TELEDYNE
ADVANCED POLLUTION INSTRUMENTATION
Everywhere**you**look™

Operation Manual

Model T100
UV Fluorescence SO₂ Analyzer

Also supports operation of: when used in conjunction with:

Model T100U Analyzer   T100U addendum, PN 06840

Model T100H Analyzer   T100H addendum, PN 07265

Model T108 Analyzer   T108 addendum, PN 07268

Model T108U Analyzer   T100U addendum, PN 06840, *and*
                                          T108 addendum, PN 07268

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ABOUT TELEDYNE ADVANCED POLLUTION INSTRUMENTATION (TAPI)

Teledyne Advanced Pollution Instrumentation™ (TAPI), a business unit of Teledyne Instruments, Inc., is a worldwide market leader in the design and manufacture of precision analytical instrumentation used for air quality monitoring, continuous emissions monitoring, and specialty process monitoring applications. Founded in San Diego, California, in 1988, TAPI introduced a complete line of Air Quality Monitoring (AQM) instrumentation, which comply with the United States Environmental Protection Administration (EPA) and international requirements for the measurement of criteria pollutants, including CO, SO_2, NO_X and Ozone.

Since 1988 TAPI has combined state-of-the-art technology, proven measuring principles, stringent quality assurance systems and world class after-sales support to deliver the best products and customer satisfaction in the business.

For further information on our company, our complete range of products, and the applications that they serve, please visit www.teledyne-api.com or contact sales@teledyne-api.com.

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IMPORTANT SAFETY INFORMATION

Important safety messages are provided throughout this manual for the purpose of avoiding personal injury or instrument damage. Please read these messages carefully. Each safety message is associated with a safety alert symbol and placed throughout this manual and inside the instrument. The symbols with messages are defined as follows:

WARNING: Electrical Shock Hazard

HAZARD: Strong oxidizer

GENERAL WARNING/CAUTION: Read the accompanying message for specific information.

CAUTION: Hot Surface Warning

Do Not Touch: Touching some parts of the instrument without protection or proper tools could result in damage to the part(s) and/or the instrument.

Technician Symbol: All operations marked with this symbol are to be performed by qualified maintenance personnel only.

Electrical Ground: This symbol inside the instrument marks the central safety grounding point for the instrument.

CAUTION
GENERAL SAFETY HAZARD

The T100 Analyzer should only be used for the purpose and in the manner described in this manual. If you use the T100 in a manner other than that for which it was intended, unpredictable behavior could ensue with possible hazardous consequences.

NEVER use any gas analyzer to sample combustible gas(es).

Note

Technical Assistance regarding the use and maintenance of the T100 or any other Teledyne API product can be obtained by contacting Teledyne API's Technical Service Department:
Phone: 800-324-5190
Email: sda_techsupport@teledyne.com
or by accessing various service options on our website at
7http://www.teledyne-api.com/.

CONSIGNES DE SÉCURITÉ

Des consignes de sécurité importantes sont fournies tout au long du présent manuel dans le but d'éviter des blessures corporelles ou d'endommager les instruments. Veuillez lire attentivement ces consignes. Chaque consigne de sécurité est représentée par un pictogramme d'alerte de sécurité; ces pictogrammes se retrouvent dans ce manuel et à l'intérieur des instruments. Les symboles correspondent aux consignes suivantes :

AVERTISSEMENT : Risque de choc électrique

DANGER : Oxydant puissant

AVERTISSEMENT GÉNÉRAL / MISE EN GARDE : Lire la consigne complémentaire pour des renseignements spécifiques

MISE EN GARDE : Surface chaude

Ne pas toucher : Toucher à certaines parties de l'instrument sans protection ou sans les outils appropriés pourrait entraîner des dommages aux pièces ou à l'instrument.

Pictogramme « technicien » : Toutes les opérations portant ce symbole doivent être effectuées uniquement par du personnel de maintenance qualifié.

Mise à la terre : Ce symbole à l'intérieur de l'instrument détermine le point central de la mise à la terre sécuritaire de l'instrument.

MISE EN GARDE

Cet instrument doit être utilisé aux fins décrites et de la manière décrite dans ce manuel. Si vous utilisez cet instrument d'une autre manière que celle pour laquelle il a été prévu, l'instrument pourrait se comporter de façon imprévisible et entraîner des conséquences dangereuses.

NE JAMAIS utiliser un analyseur de gaz pour échantillonner des gaz combustibles!

WARRANTY

WARRANTY POLICY (02024 F)

Teledyne Advanced Pollution Instrumentation (TAPI), a business unit of Teledyne Instruments, Inc., provides that:

Prior to shipment, TAPI equipment is thoroughly inspected and tested. Should equipment failure occur, TAPI assures its customers that prompt service and support will be available.

COVERAGE

After the warranty period and throughout the equipment lifetime, TAPI stands ready to provide on-site or in-plant service at reasonable rates similar to those of other manufacturers in the industry. All maintenance and the first level of field troubleshooting are to be performed by the customer.

NON-TAPI MANUFACTURED EQUIPMENT

Equipment provided but not manufactured by TAPI is warranted and will be repaired to the extent and according to the current terms and conditions of the respective equipment manufacturer's warranty.

Product Return

All units or components returned to Teledyne API should be properly packed for handling and returned freight prepaid to the nearest designated Service Center. After the repair, the equipment will be returned, freight prepaid.

The complete Terms and Conditions of Sale can be reviewed at http://www.teledyne-api.com/terms_and_conditions.asp

ATTENTION

AVOID WARRANTY INVALIDATION

Failure to comply with proper anti-Electro-Static Discharge (ESD) handling and packing instructions and Return Merchandise Authorization (RMA) procedures when returning parts for repair or calibration may void your warranty. For anti-ESD handling and packing instructions please refer to "Packing Components for Return to Teledyne API" in the Primer on Electro-Static Discharge section of this manual, and for RMA procedures please refer to our Website at http://www.teledyne-api.com under Customer Support > Return Authorization.

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ABOUT THIS MANUAL

Presented here is information regarding the documents that are included with this manual (Structure), its history of release and revisions (Revision History), how the content is organized (Organization), and the conventions used to present the information in this manual (Conventions Used).

STRUCTURE

This T100 manual, PN 06807, is comprised of multiple documents, assembled in PDF format, as listed below.

Part No.	Rev	Name/Description
06807	C	Operation Manual, T100 UV Fluorescence SO2 Analyzer
05036	F	Appendix A, Menu Trees and related software documentation
06845	A	Spare Parts List (in Appendix B of this manual)
04357	A	AKIT, Expendables, basic (in Appendix B of this manual)
01475	A	AKIT, Expendables, IZS (in Appendix B of this manual)
04728	A	AKIT, Spares (in Appendix B of this manual)
04796	F	Appendix C, Repair Form
06908	A	Interconnect Diagram (in Appendix D of this manual)
069080100	A	Interconnect Table (in Appendix D of this manual)

Schematics (in Appendix D of this manual)

Part No.	Rev	Name/Description
04354	D	PCA, 04003, Pressure Flow Sensor Board
04524	D	PCA, 04522, Relay Card
04181	H	PCA, 04180, PMT Preamp
05064	C	PCA, 05063, Dual UV Detector
04693	E	PCA, 04692, UV Lamp Driver
04932	C	PCA, Thermo-Electric Cooler Driver
04468	B	PCA, 04467, Analog Output Isolator
05803	B	SCH, PCA 05802, MOTHERBOARD, GEN-5
06698	D	SCH, PCA 06670, INTRFC, LCD TCH SCRN,
06882	B	SCH, LVDS TRANSMITTER BOARD
06731	B	SCH, AUX-I/O BOARD

Note   **We recommend that this manual be read in its entirety before any attempt is made to operate the instrument.**

ORGANIZATION

This manual is divided among three main parts and a collection of appendices at the end.

Part I contains introductory information that includes an overview of the analyzer, specifications, descriptions of the available options, installation and connection instructions, and the initial calibration and functional checks.

Part II comprises the operating instructions, which include initial functional checks and calibration, basic, advanced and remote operation, advanced calibration, diagnostics, testing, and ends with specifics of calibrating for use in EPA monitoring.

Part III provides detailed technical information, starting with maintenance, troubleshooting and service, followed by principles of operation, Frequently Asked Questions (FAQs) and a glossary. It also contains a special section dedicated to providing information about electro-static discharge and protecting against its consequences.

The appendices at the end of this manual provide support information such as, version-specific software documentation, lists of spare parts and recommended stocking levels, and schematics.

CONVENTIONS USED

In addition to the safety symbols as presented in the *Important Safety Information* page, this manual provides *special notices* related to the safety and effective use of the analyzer and other pertinent information.

Special Notices appear as follows:

ATTENTION

COULD DAMAGE INSTRUMENT AND VOID WARRANTY
This special notice provides information to avoid damage to your instrument and possibly invalidate the warranty.

IMPORTANT

IMPACT ON READINGS OR DATA
Could either affect accuracy of instrument readings or cause loss of data.

Note

Pertinent information associated with the proper care, operation or maintenance of the analyzer or its parts.

REVISION HISTORY

This section provides information regarding the history of changes to this manual.

T100 Manual, PN06807			
Date	**Rev**	**DCN**	**Change Summary**
2013 Apr 22	C	6650	Administrative corrections; technical corrections
2011 Aug 22	B	6192	Administrative change: reorganized structure. Technical Updates: added MODBUS Quick Setup (Section 6.6.1), update Appendices A and D with latest revisions.
2010 Sep 7	A	5834	Initial release

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PART I

GENERAL INFORMATION

1. INTRODUCTION, FEATURES AND OPTIONS

This section provides an overview of the Model T100 Analyzer, its features and its options, followed by a description of how this user manual is arranged.

1.1. T100 OVERVIEW

The Model T100 (also referred to as T100) UV Fluorescence SO_2 Analyzer is a microprocessor controlled analyzer that determines the concentration of sulfur dioxide (SO_2), in a sample gas drawn through the instrument's sample chamber where it is exposed to ultraviolet light, which causes any SO_2 present to fluoresce. The instrument measures the amount of fluorescence to determine the amount of SO_2 present in the sample gas.

The T100's exceptional stability is achieved with the use of an optical shutter to compensate for sensor drift and a reference detector to correct for changes in UV lamp intensity. Additionally an advanced optical design combined with a special scrubber, called a "kicker" that removes hydrocarbons (which fluoresces similarly to SO_2) prevents inaccuracies due to interferents.

Calibration of the instrument is performed in software which stores SO_2 concentration measurements made gas with when specific, known concentrations of SO_2 are supplied to the analyzer. The microprocessor uses these calibration values along with other performance parameters such as the sensor offset, UV lamp intensity and the amount of stray light present and measurements of the temperature and pressure of the sample gas to compute the final SO_2 concentration.

Built-in data acquisition capability, using the analyzer's internal memory, allows the logging of multiple parameters including averaged or instantaneous concentration values, calibration data, and operating parameters such as pressure and flow rate. Stored data are easily retrieved through the serial port or optional Ethernet port via our APICOM software or from the front panel, allowing operators to perform predictive diagnostics and enhanced data analysis by tracking parameter trends. Multiple averaging periods of one minute to 365 days are available for over a period of one year.

1.2. FEATURES

The features of your T100 UV Fluorescence Sulfur Dioxide Analyzer include:

- LCD Graphical User Interface with capacitive touch screen

- Ranges, 0-50 ppb to 0-20,000 ppb, user selectable

- Dual ranges and auto ranging

- Microprocessor control for versatility

- Multi-tasking software to allow viewing test variables while operating

- Continuous self checking with alarms

- Bi-directional USB, RS-232, and 10/100Base-T Ethernet ports for remote operation (optional RS-485)

- Front panel USB ports for peripheral devices

- Digital status outputs to indicate instrument operating condition

- Adaptive signal filtering to optimize response time

- Temperature and Pressure compensation

- Internal Zero and Span check (optional)

- Internal data logging with 1 min to 365 day multiple averages

- Critical flow orifices to provide flow stability

1.3. T100 DOCUMENTATION

In addition to this operation manual (part number 06807), the APICOM and DAS manual (PN 07463) is available for download from Teledyne API's website at http://www.teledyne-api.com/manuals/, to support the operation of this instrument.

1.4. OPTIONS

The options available for your analyzer are presented in Table 1-1 with name, option number, a description and/or comments, and if applicable, cross-references to technical details in this manual, such as setup and calibration. To order these options or to learn more about them, please contact the Sales department of Teledyne - Advanced Pollution Instruments at:

TOLL-FREE:	800-324-5190
TEL:	+1 858-657-9800
FAX:	+1 858-657-9816
E-MAIL:	apisales@teledyne.com
WEB SITE:	http://www.teledyne-api.com/

Table 1-1: Analyzer Options

OPTION	OPTION NUMBER	DESCRIPTION/NOTES	REFERENCE
Pumps		**Pumps meet all typical AC power supply standards while exhibiting same pneumatic performance.**	
	10A	External Pump 100V - 120V @ 60 Hz	N/A
	10B	External Pump 220V - 240V @ 50 Hz	N/A
	10C	External Pump 220V - 240V @ 60 Hz	N/A
	10D	External Pump 100V - 120V @ 50 Hz	N/A
	10E	External Pump 100V @ 60 Hz	N/A
	11B	Pumpless, internal or external Pump Pack	N/A
	13	High Voltage Internal Pump 240V @ 50Hz	N/A
Rack Mount Kits		**Options for mounting the analyzer in standard 19" racks**	
	20A	Rack mount brackets with 26 in. chassis slides	N/A
	20B	Rack mount brackets with 24 in. chassis slides	N/A
	21	Rack mount brackets only (compatible with carrying strap, Option 29)	N/A
	23	Rack mount for external pump pack (no slides)	N/A
Carrying Strap/Handle		**Side-mounted strap for hand-carrying analyzer**	
	29	Extends from "flat" position to accommodate hand for carrying. Recesses to 9mm (3/8") dimension for storage. Can be used with rack mount brackets, Option 21. Cannot be used with rack mount slides.	N/A

<div align="center">

CAUTION
GENERAL SAFETY HAZARD

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A FULLY LOADED T100 WITH VALVE OPTIONS WEIGHS ABOUT 18 KG (40 POUNDS).
To avoid personal injury we recommend that two persons lift and carry the analyzer. Disconnect all cables and tubing from the analyzer before moving it.

OPTION	OPTION NUMBER	DESCRIPTION/NOTES	REFERENCE
Analog Inputs		Used for connecting external voltage signals from other instrumentation (such as meteorological instruments).	
	64	Also can be used for logging these signals in the analyzer's internal DAS	Sections 3.3.1.2 and 0
Current Loop Analog Outputs		**Adds isolated, voltage-to-current conversion circuitry to the analyzer's analog outputs.**	
	41	Can be configured for any output range between 0 and 20 mA. May be ordered separately for any of the analog outputs. Can be installed at the factory or retrofitted in the field.	Sections 3.3.1.4, 5.4.1, 5.9.3, and 5.9.3.5
Parts Kits		**Spare parts and expendables**	
	42A	**Expendables Kit** includes a recommended set of expendables for one year of operation of this instrument including replacement sample particulate filters.	Appendix B
	43	**Expendables Kit with IZS** includes the items needed to refurbish the internal zero air scrubber (IZS) that is included.	Appendix B
	45	**Spare Parts Kit** includes spares parts for one unit.	Appendix B
NO Optical Filter		**Recommended for high NOX backgrounds.**	
	47	Required for EN Certification.	N/A

OPTION	OPTION NUMBER	DESCRIPTION/NOTES			REFERENCE
Calibration Valves		**Used to control the flow of calibration gases generated from external sources, rather than manually switching the rear panel pneumatic connections.**			
	50A	Two Teflon® solenoid valve sets located inside the analyzer: **Zero/Span** valve switches between zero air and span gas; **Sample/Cal** valve switches between sample gas and calibration gas.			Sections 3.3.2.3, 3.3.2.4, 9.4, 9.5 and 9.6
Internal Zero/Span (IZS) Gas Generator		**Generates internal zero air and span gas.**			
	51A	Includes heated enclosure for a permeation tube (tube not included – see SO$_2$ IZS Permeation Tubes options), an external scrubber for producing zero air and a set of valves for switching between the sample gas inlet and the output of the zero/span subsystem, functionally very similar to the valves included in the zero/span valve option.			Sections 3.3.2.4, 9.5, 11.3.2 and 12.6.17
SO$_2$ IZS Permeation Tubes		**Replacement tubes for the IZS option; identical size/shape; different effusion rates.**			
		Effusion Rate (@ 50°C)	Approximate Concentration	Specified Flow Rate (of indicated perm tube rate)	
	52C	796 ng/min	0.3-0.5 ppm	0.76 ± 5% lpm	N/A
	52H	1592 ng/min	0.8 ppm	0.76 ± 50% lpm	N/A
	52M	220 ng/min	150 ppb	0.56 ± 25% lpm	N/A
		Each tube comes with a calibration certificate, traceable to a NIST standard, specifying its actual effusion rate of that tube to within ± 5% when immersed in a gas stream moving at the specified flow rate. This calibration is performed at a tube temperature of 50°C.			Sections 3.3.2.4, 9.1.1.3 and 10.1.4
Communication Cables		**For remote serial, network and Internet communication with the analyzer.**			
		Type	Description		
	60A	RS-232	Shielded, straight-through DB-9F to DB-25M cable, about 1.8 m long. Used to interface with older computers or code activated switches with DB-25 serial connectors.		Section 3.3.1.8 and 6.3
	60B	RS-232	Shielded, straight-through DB-9F to DB-9F cable of about 1.8 m length.		Sections 3.3.1.8, and 6.3, and 7.2.7
	60C	Ethernet	Patch cable, 2 meters long, used for Internet and LAN communications.		Sections 3.3.1.8 and 6.5
	60D	USB	Cable for direct connection between instrument (rear panel USB port) and personal computer.		Sections 3.3.1.8 and 6.5.1
Concentration Alarm Relay		**Issues warning when gas concentration exceeds limits set by user.**			
	61	Four (4) "dry contact" relays on the rear panel of the instrument. This relay option is different from and in addition to the "Contact Closures" that come standard on all TAPI instruments.			Sections 3.3.1.7 and 3.4.4
RS-232 Multidrop		**Enables communications between host computer and up to eight analyzers.**			
	62	Multidrop card seated on the analyzer's CPU card. Each instrument in the multidrop network requires this card and a communications cable (Option 60B).			Section 3.3.1.8

OPTION	OPTION NUMBER	DESCRIPTION/NOTES	REFERENCE
Second Gas Sensors		**Choice of one additional gas sensor.**	
	65A	Oxygen (O_2) Sensor	• Section 2.1 (specs) • Section 3.3.2.8, (pneumatic layout) • Section 9.10.1 (calibration) • Section 13.2 for principles of operation
	67A	Carbon Dioxide (CO_2) Sensor	• Section 2.1 (specs) • Section 3.3.2.9 (pneumatic layout) • Section 9.10.2 (calibration) • Section 13.3 (principles of operation)
Special Features		**Built in features, software activated**	
	N/A	**Maintenance Mode Switch**, located inside the instrument, places the analyzer in maintenance mode where it can continue sampling, yet ignore calibration, diagnostic, and reset instrument commands. This feature is of particular use for instruments connected to Multidrop or Hessen protocol networks. Call Technical Support for activation.	N/A
	N/A	**Second Language Switch** activates an alternate set of display messages in a language other than the instrument's default language. Call Technical Support for a specially programmed Disk on Module containing the second language.	N/A
	N/A	**Dilution Ratio Option** allows the user to compensate for diluted sample gas, such as in continuous emission monitoring (CEM) where the quality of gas in a smoke stack is being tested and the sampling method used to remove the gas from the stack dilutes the gas. Call Technical Support for activation.	Section 3.4.4.1, 5.4.5 and 13.1.9.3

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2. SPECIFICATIONS, APPROVALS & COMPLIANCE

This section presents specifications for the T100 analyzer and the O_2 and CO_2 sensor options, Agency approvals, EPA equivalency designation, and CE mark compliance.

2.1. SPECIFICATIONS AND APPROVALS

Table 2-1 T100 Basic Unit Specifications

Parameter	Description
Ranges (Physical Analog Output)	Min: 0-50 ppb Full Scale Max: 0-20,000 ppb Full Scale (selectable, dual ranges and auto ranging supported)
Measurement Units	ppb, ppm, µg/m^3, mg/m^3 (selectable)
Zero Noise[1]	< 0.2 ppb (RMS)
Span Noise[1]	< 0.5% of reading, above 50 ppb
Lower Detectable Limit[2]	0.4 ppb
Zero Drift	< 0.5 ppb/24 hours
Span Drift	< 0.5% of full scale/24 hours
Lag Time[1]	20 seconds
Rise/Fall Time[1]	<100 sec to 95%
Linearity	1% of full scale
Precision[1]	0.5% of reading above 50 ppb
Sample Flow Rate	650 cm^3/min. ±10%
Power Requirements	100V-120V, 60Hz (165W); 220V-240V, 50 Hz (140W)
Analog Output Ranges	10 V, 5 V, 1 V, 0.1 V (selectable)
Recorder Offset	± 10 %
Standard I/O	1 Ethernet: 10/100Base-T 2 RS-232 (300 – 115,200 baud) 2 USB device ports 8 opto-isolated digital outputs 6 opto-isolated digital inputs 4 analog outputs
Optional I/O	1 USB com port 1 RS485 8 analog inputs (0-10V, 12-bit) 4 digital alarm outputs Multidrop RS232 3 4-20mA current outputs

Parameter	Description
Environmental	Installation category (over-voltage category) II; Pollution degree 2
Operating Temperature	5 - 40 $^{\circ}$C (with EPA Equivalency)
Humidity Range	0 - 95% RH, non-condensing
Dimensions HxWxD	7" x 17" x 23.5" (178 mm x 432 mm x 597 mm)
Weight	31 lbs (14 kg); 35.7 lbs (16 kg) with internal pump
[1] As defined by the USEPA. [2] Defined as twice the zero noise level by the USEPA.	

Table 2-2: O$_2$ Sensor Option Specifications

Parameter	Description
Ranges	0-1% to 0-100% user selectable. Dual ranges and auto-ranging supported.
Zero Noise[1]	<0.02% O_2
Lower Detectable Limit[2]	<0.04% O_2
Zero Drift (24 hours)[3]	<± 0.02% O_2
Zero Drift (7 days)	<±- 0.05% O_2
Span Noise[1]	<± 0.05% O_2
Span Drift (7 days)	<± 0.1% O_2
Accuracy	(intrinsic error) <± 0.1% O_2
Linearity	<± 0.1 % O_2
Temp Coefficient	<± 0.05% O_2 /°C,
Rise and Fall Time	<60 seconds to 95%
[1] As defined by the USEPA [2] Defined as twice the zero noise level by the USEPA [3] Note: zero drift is typically <± 0.1% O_2 during the first 24 hrs of operation	

Table 2-3: CO2 Sensor Option Specifications

Parameter	Description
Ranges	0-1% to 0-20% user selectable. Dual ranges and auto-ranging supported.
Zero Noise[1]	<0.02% CO_2
Zero Drift (24 hours)	<± 0.02% CO_2
Zero Drift (7 days)	<± 0.05% CO_2
Span Noise[1]	<± 0.1% CO_2
Span Drift (7 days)	<± 0.1% CO_2
Lower Detectable Limit[2]	<0.04% CO_2
Accuracy	<± (0.02% CO_2 + 2% of reading)
Linearity	<± 0.1% CO_2
Temperature Coefficient	<± 0.01% CO_2 /°C
Rise and Fall Time	<60 seconds to 95%
[1] As defined by the USEPA [2] Defined as twice the zero noise level by the USEPA	

2.2. EPA EQUIVALENCY DESIGNATION

The T100 Analyzer is designated as Reference Method Number EQSA-0495-100 as per 40 CFR Part 53 when operated under the following conditions:

- Range: Any range from 50 parts per billion (ppb) to 10 parts per million (ppm)

- Ambient temperature range of 5 $^{\circ}$C to 40 $^{\circ}$C

- Line voltage range of 100-120 VAC or 220-240 VAC, at 50 or 60 Hz

- Sample filter: Equipped with PTFE filter element in the internal filter assembly

- Sample flow of 650 +/- 65 cm^3/min

- Vacuum pump (internal) capable of 14"Hg Absolute pressure @ 1 slpm or better

- Software settings:

Dynamic span	OFF
Dynamic zero	OFF
Dilution factor	OFF
AutoCal	ON or OFF
Dual range	ON or OFF
Auto-range	ON or OFF
Temp/Pressure compensation	ON

Under this designation, the analyzer may be operated with or without the following optional equipment:

- Rack mount with chassis slides

- Rack mount without slides, ears only

- Zero/span valve options.

- Internal zero/span (IZS) option with either:

    - SO$_2$ permeation tube - 0.4ppm at 0.7 liter per minute; certified/uncertified, or

    - SO$_2$ permeation tube - 0.8 ppm at 0.7 liter per minute; certified/uncertified. Under the designation, the IZS option cannot be used as the source of calibration

- 4-20mA isolated analog outputs

- Status outputs

- Control inputs

- RS-232 output

- Ethernet output

- Zero air scrubber

- 4-20mA, isolated output

2.3. APPROVALS AND CERTIFICATIONS

The Teledyne API Model T100 analyzer was tested and certified for Safety and Electromagnetic Compatibility (EMC). This section presents the compliance statements for those requirements and directives..

2.3.1. EMC

EN 61326-1 (IEC 61326-1), Class A Emissions/Industrial Immunity

EN 55011 (CISPR 11), Group 1, Class A Emissions

FCC 47 CFR Part 15B, Class A Emissions

CE: 2004/108/EC, Electromagnetic Compatibility Directive

2.3.2. SAFETY

IEC 61010-1:2001, Safety requirements for electrical equipment for measurement, control, and laboratory use.

CE: 2006/95/EC, Low-Voltage Directive

North American:
cNEMKO (Canada): CAN/CSA-C22.2 No. 61010-1-04
NEMKO-CCL (US): UL No. 61010-1 (2nd Edition)

2.3.3. OTHER TYPE CERTIFICATIONS

MCERTS: Sira MC 050067/04

For additional certifications, please contact Technical Support:

Toll-free Phone: 800-324-5190
Phone: 858-657-9800
Fax: 858-657-9816
Email: sda_techsupport@teledyne.com

3. GETTING STARTED

This section addresses the procedures for unpacking the instrument and inspecting for damage, presents clearance specifications for proper ventilation, introduces the instrument layout, then presents the procedures for getting started: making electrical and pneumatic connections, and conducting an initial calibration check.

3.1. UNPACKING THE T100 ANALYZER

⚠	**CAUTION** **GENERAL SAFETY HAZARD** To avoid personal injury, always use two persons to lift and carry the T100.

ATTENTION

COULD DAMAGE INSTRUMENT AND VOID WARRANTY

Printed Circuit Assemblies (PCAs) are sensitive to electro-static discharges too small to be felt by the human nervous system. Failure to use ESD protection when working with electronic assemblies will void the instrument warranty. Refer to Section 13 for more information on preventing ESD damage.

⚠	**CAUTION** Do not operate this instrument until you've removed dust plugs from SAMPLE and EXHAUST ports on the rear panel!

Note

Teledyne API recommends that you store shipping containers/materials for future use if/when the instrument should be returned to the factory for repair and/or calibration service. See Warranty section in this manual and shipping procedures on our Website at http://www.teledyne-api.com under Customer Support > Return Authorization.

Verify that there is no apparent external shipping damage. If damage has occurred, please advise the shipper first, then Teledyne API.

Included with your analyzer is a printed record of the final performance characterization performed on your instrument at the factory. It is titled *Final Test and Validation Data Sheet* (*P/N 04551*). This record is an important quality assurance and calibration record for this instrument. It should be placed in the quality records file for this instrument.

With no power to the unit, carefully remove the top cover of the analyzer and check for internal shipping damage by carrying out the following steps:

1. Remove the locking screw located in the top, center of the Front panel;

2. Remove the two flat head, Phillips screws on the sides of the instrument;

3. Slide the cover backwards until it clears the analyzer's front bezel, and;

4. Lift the cover straight up.

5. Inspect the interior of the instrument to ensure that all circuit boards and other components are in good shape and properly seated.

6. Check the connectors of the various internal wiring harnesses and pneumatic hoses to ensure that they are firmly and properly seated.

7. Verify that all of the optional hardware ordered with the unit has been installed. These are listed on the paperwork accompanying the analyzer.

⚠️	**WARNING** **ELECTRICAL SHOCK HAZARD** **Never disconnect PCAs, wiring harnesses or electronic subassemblies while under power.**

3.1.1. VENTILATION CLEARANCE

Whether the analyzer is set up on a bench or installed into an instrument rack, be sure to leave sufficient ventilation clearance.

Table 3-1: Ventilation Clearance

AREA	MINIMUM REQUIRED CLEARANCE
Back of the instrument	**4 in.**
Sides of the instrument	**1 in.**
Above and below the instrument	**1 in.**

Various rack mount kits are available for this analyzer. Refer to Section 1.4 of this manual for more information.

3.2. INSTRUMENT LAYOUT

Instrument layout includes front panel and display, rear panel connectors, and internal chassis layout.

3.2.1. FRONT PANEL

Figure 3-1 shows the analyzer's front panel layout, followed by a close-up of the display screen in Figure 3-2, which is described in Table 3-2. The two USB ports on the front panel are provided for the connection of peripheral devices:

- plug-in mouse (not included) to be used as an alternative to the touchscreen interface

- thumb drive (not included) to download updates to instruction software (contact TAPI Technical Support for information).
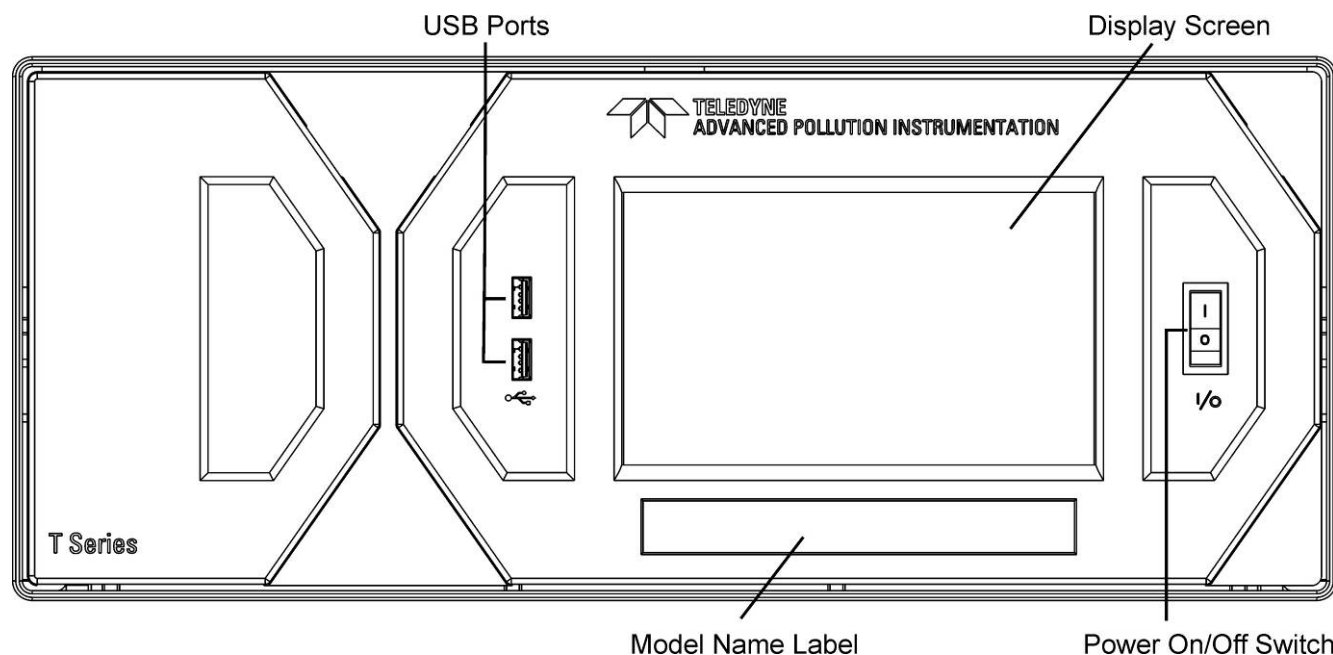
Figure 3-1: Front Panel Layout

Figure 3-2: Display Screen and Touch Control

The front panel liquid crystal display screen includes touch control. Upon analyzer start-up, the screen shows a splash screen and other initialization indicators before the main display appears, similar to Figure 3-2 above (may or may not display a Fault alarm). The LEDs on the display screen indicate the Sample, Calibration and Fault states; also on the screen is the gas concentration field (Conc), which displays real-time readouts for the primary gas and for the secondary gas if installed. The display screen also shows what mode the analyzer is currently in, as well as messages and data (Param). Along the bottom of the screen is a row of touch control buttons; only those that are currently applicable will have a label. Table 3-2 provides detailed information for each component of the screen.

ATTENTION   **COULD DAMAGE INSTRUMENT AND VOID WARRANTY**

Do not use hard-surfaced instruments such as pens to touch the control buttons.

Table 3-2: Display Screen and Touch Control Description

Field	Description/Function			
Status	LEDs indicating the states of Sample, Calibration and Fault, as follows:			
	Name	Color	State	Definition
	SAMPLE	Green	Off	Unit is not operating in sample mode, DAS is disabled.
			On	Sample Mode active; Front Panel Display being updated; DAS data being stored.
			Blinking	Unit is operating in sample mode, front panel display being updated, DAS hold-off mode is ON, DAS disabled
	CAL	Yellow	Off	Auto Cal disabled
			On	Auto Cal enabled
			Blinking	Unit is in calibration mode
	FAULT	Red	Off	No warnings exist
			Blinking	Warnings exist
Conc	Displays the actual concentration of the sample gas currently being measured by the analyzer in the currently selected units of measure			
Mode	Displays the name of the analyzer's current operating mode			
Param	Displays a variety of informational messages such as warning messages, operational data, test function values and response messages during interactive tasks.			
Control Buttons	Displays dynamic, context sensitive labels on each button, which is blank when inactive until applicable.			

Figure 3-3 shows how the front panel display is mapped to the menu charts illustrated in this manual. The **Mode**, **Param** (parameters), and **Conc** (gas concentration) fields in the display screen are represented across the top row of each menu chart. The eight touch **control buttons** along the bottom of the display screen are represented in the bottom row of each menu chart.

Menu Chart Layout

[Mode]   [Param]   [Conc]

[…………………..…   Touch Control Buttons   …………….………]

Display Example:

SAMPLE
CAL
FAULT

Conc
SO2   386.425 PPB

Mode
SAMPLE

Param
SYSTEM RESET

TEST   CAL   CLR   SETUP

Menu Chart Representing Display Example:

SAMPLE   SYSTEM RESET   SO2 386.425 PPB

TEST   CAL   CLR   SETUP
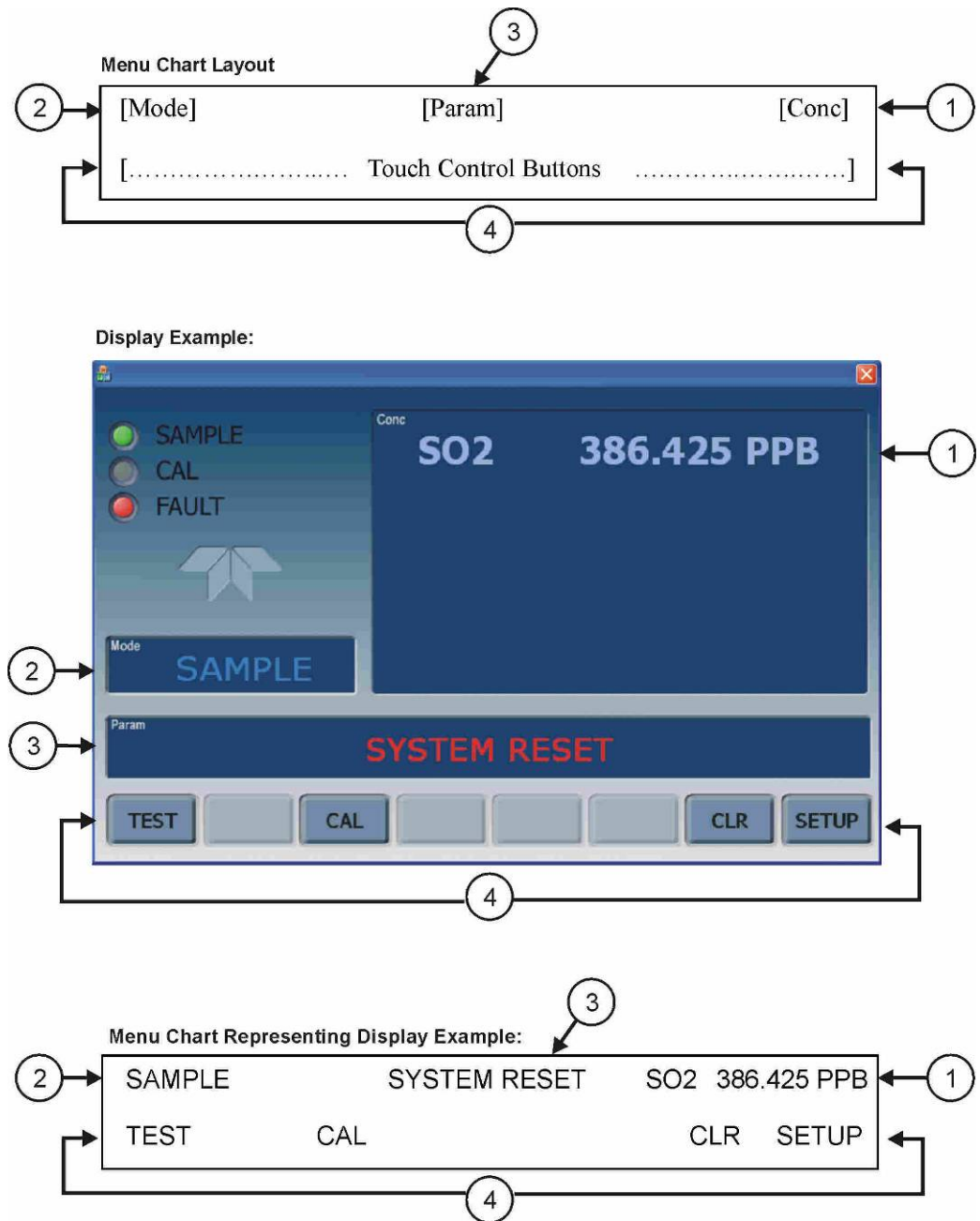
Figure 3-3:   Display/Touch Control Screen Mapped to Menu Charts

Note   **The menu charts in this manual contain condensed representations of the analyzer's display during the various operations being described. These menu charts are not intended to be exact visual representations of the actual display.**

3.2.2. REAR PANEL
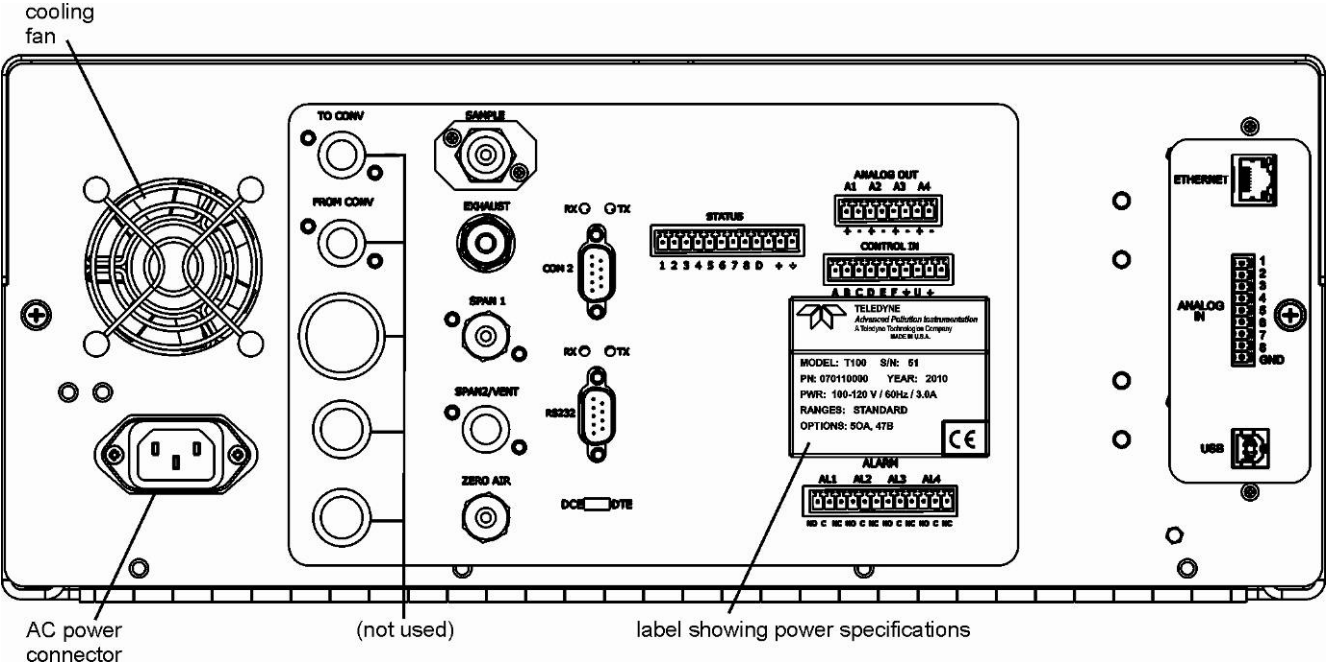
Figure 3-4: Rear Panel Layout

Table 3-3 provides a description of each component on the rear panel.

Table 3-3: Rear Panel Description

Component	Function
cooling fan	Pulls ambient air into chassis through side vents and exhausts through rear.
⚠️ AC power connector	Connector for three-prong cord to apply AC power to the analyzer. **CAUTION! The cord's power specifications (specs) MUST comply with the power specs on the analyzer's rear panel Model number label**
Model/specs label	Identifies the analyzer model number and provides power specs
TO CONV	(not used in this model)
FROM CONV	(not used in this model)
SAMPLE	Connect a gas line from the source of sample gas here. Calibration gases are also inlet here on units without zero/span/shutoff valve options installed.
EXHAUST	Connect an exhaust gas line of not more than 10 meters long here that leads outside the shelter or immediate area surrounding the instrument.
SPAN 1	On units with zero/span/shutoff valve options installed, connect a gas line to the source of calibrated span gas here.
SPAN2/VENT	Used as a second cal gas input line when instrument is configured with zero/span valves and a dual gas option, or as a cal gas vent line when instrument is configured with a pressurized span option *(Call factory for details)*.
ZERO AIR	Internal Zero Air: On units with zero/span/shutoff valve options installed but no internal zero air scrubber attach a gas line to the source of zero air here.
RX TX	LEDs indicate receive (RX) and transmit (TX) activity on the when blinking.
COM 2	Serial communications port for RS-232 or RS-485.
RS-232	Serial communications port for RS-232 only.
DCE DTE	Switch to select either data terminal equipment or data communication equipment during RS-232 communication. (Section 6.1).
STATUS	For outputs to devices such as Programmable Logic Controllers (PLCs).
ANALOG OUT	For voltage or current loop outputs to a strip chart recorder and/or a data logger.
CONTROL IN	For remotely activating the zero and span calibration modes.
ALARM	Option for concentration alarms and system warnings.
ETHERNET	Connector for network or Internet remote communication, using Ethernet cable
ANALOG IN	Option for external voltage signals from other instrumentation and for logging these signals
USB	Connector for direct connection to personal computer, using USB cable.
Information Label	Includes voltage and frequency specifications

3.2.3. INTERNAL CHASSIS LAYOUT

Figure 3-5 illustrates the internal layout of the chassis without options. Section 3.3.2 shows pneumatic diagrams for the basic configuration and for options.
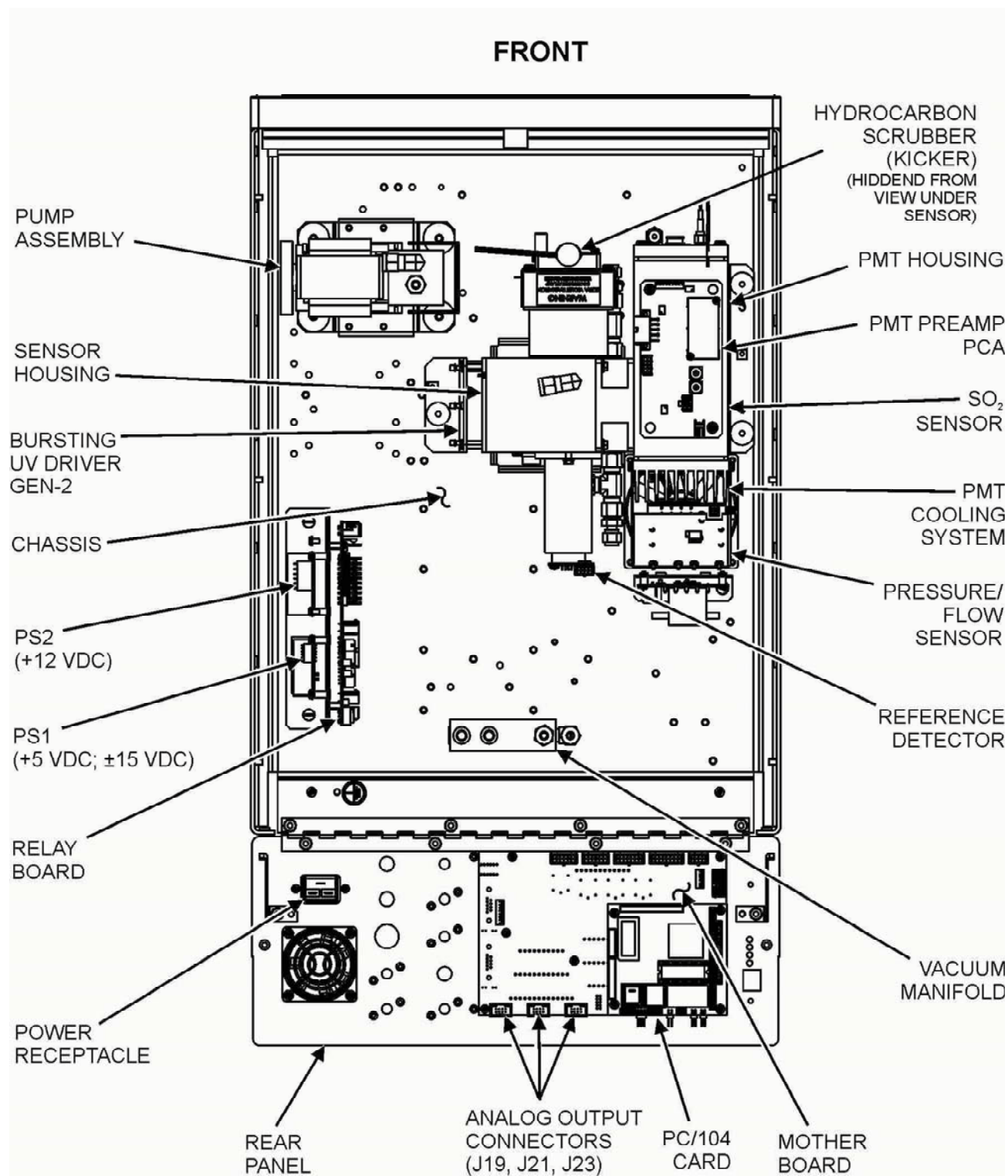
Figure 3-5: Internal Layout, Basic (no Valve or Second Gas Options)

3.3. CONNECTIONS AND SETUP

This section presents the electrical (Section 3.3.1) and pneumatic (Section 3.3.2) connections for setup and preparing for instrument operation.

3.3.1. ELECTRICAL CONNECTIONS

Note	**To maintain compliance with EMC standards, it is required that the cable length be no greater than 3 meters for all I/O connections, which include Analog In, Analog Out, Status Out, Control In, Ethernet/LAN, USB, RS-232, and RS-485.**

This section provides instructions for basic connections and for options. Table 3-4 provides a direct link to the instructions for the subsections that apply to your analyzer's configuration.

Table 3-4: Electrical Connections References

Connection	Section
Power	3.3.1.1
Analog Inputs (Option)	3.3.1.2
Analog Outputs	3.3.1.3
Current Loop Analog Outputs (Option), and converting current to voltage output	3.3.1.4
Status Outputs	3.3.1.5
Control Inputs	3.3.1.6
Concentration Alarm Relay (Option)	3.3.1.7
Communications (Ethernet, USB, RS-232, Multidrop, RS-485)*	3.3.1.8
* USB is an option with exceptions. * RS-485 is an option and requires special setup (contact the Factory). Either USB or RS-485 can be used; not both.	

3.3.1.1. CONNECTING POWER

Attach the power cord to the analyzer and plug it into a power outlet capable of carrying at least 10 Amps of current at your AC voltage and that it is equipped with a functioning earth ground.

WARNING
ELECTRICAL SHOCK HAZARD

High Voltages are present inside the analyzers case.

Power connection must have functioning ground connection.

Do not defeat the ground wire on power plug.

Power off analyzer before disconnecting or connecting electrical subassemblies.

Do not operate analyzer with the cover off.

CAUTION
GENERAL SAFETY HAZARD

The T100 analyzer can be configured for both 100-120 V and 220-240 V at either 50 or 60 Hz.

To avoid damage to your analyzer, ensure that the AC power voltage matches the voltage indicated on the Analyzer's model identification label (refer to Figure 3-4) before plugging the T100 into line power.

3.3.1.2. CONNECTING ANALOG INPUTS (OPTION)

The Analog In connector is used for connecting external voltage signals from other instrumentation (such as meteorological instruments) and for logging these signals in the analyzer's internal DAS. The input voltage range for each analog input is 1-10 VDC, and input impedance is nominally 20kΩ in parallel with 0.1μF.
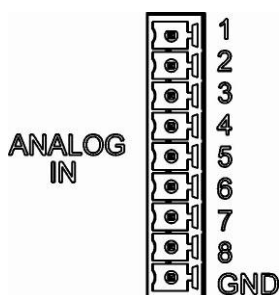
Figure 3-6: Analog In Connector

Pin assignments for the Analog In connector are presented in Table 3-5 .

Table 3-5: Analog Input Pin Assignments

PIN	DESCRIPTION	DAS PARAMETER[1]
1	Analog input # 1	AIN 1
2	Analog input # 2	AIN 2
3	Analog input # 3	AIN 3
4	Analog input # 4	AIN 4
5	Analog input # 5	AIN 5
6	Analog input # 6	AIN 6
7	Analog input # 7	AIN 7
8	Analog input # 8	AIN 8
GND	Analog input Ground	N/A
[1] See Section 0 for details on setting up the DAS.		

3.3.1.3. CONNECTING ANALOG OUTPUTS

The T100 is equipped with several analog output channels accessible through a connector on the rear panel of the instrument. The standard configuration for these outputs is mVDC. An optional current loop output is available for each. (Section 3.3.1.4).

When the instrument is in its default configuration, channels A1 and A2 output a signal that is proportional to the SO_2 concentration of the sample gas. Either can be used for connecting the analog output signal to a chart recorder or for interfacing with a datalogger.

Output A3 is only used on the T100 if the optional O_2 or CO_2 sensor is installed.

Channel A4 is special. It can be set by the user (refer to Section 5.9.9) to output any one of the parameters accessible through the **<TST TST>** buttons of the unit's sample display.

To access these signals attach a strip chart recorder and/or data-logger to the appropriate analog output connections on the rear panel of the analyzer.
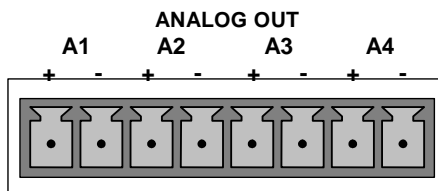
Figure 3-7: Analog Output Connector

Table 3-6:   Analog Output Pin Assignments

PIN	ANALOG OUTPUT	VOLTAGE SIGNAL	CURRENT SIGNAL
1	A1	V Out	I Out +
2		Ground	I Out -
3	A2	V Out	I Out +
4		Ground	I Out -
5	A3 (Only used if an optional O_2 or CO_2 sensor is installed)	V Out	I Out +
6		Ground	I Out -
7	A4	V Out	I Out +
8		Ground	I Out -

3.3.1.4. CURRENT LOOP ANALOG OUTPUTS (OPTION 41) SETUP

If your analyzer had this option installed at the factory, there are no further connections to be made. The current loop option can be configured for any output range between 0 and 20 mA. Section 5.9.3.5 provides information on calibrating or adjusting these outputs.

This section provides instructions for setting up the analog outputs for voltage and/or current output. Figure 3-8 provides installation instructions and illustrates a sample combination of one current output and two voltage outputs configuration.

- For current output install the Current Loop option PCA on J19, on J21 or on J23 of the motherboard.

- For voltage output, install jumpers on J19, J21 and/or J23.

Following Figure 3-8 are instructions for converting current loop analog outputs to standard 0-to-5 VDC outputs.

CAUTION – AVOID INVALIDATING WARRANTY

Servicing or handling of circuit components requires electrostatic discharge protection, i.e. ESD grounding straps, mats and containers. Failure to use ESD protection when working with electronic assemblies will void the instrument warranty. Refer to Section 13 for more information on preventing ESD damage.
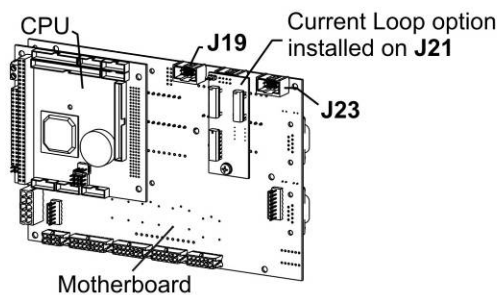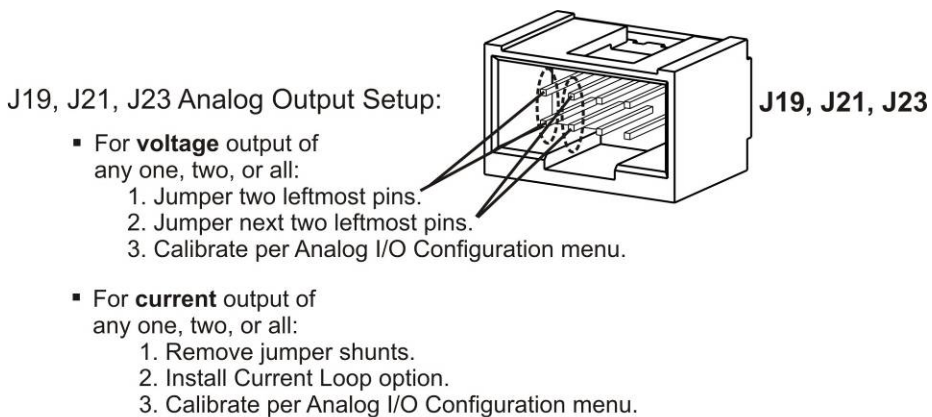
Figure 3-8: Current Loop Option Installed on the Motherboard

CONVERTING CURRENT LOOP ANALOG OUTPUTS TO STANDARD VOLTAGE OUTPUTS

To convert an output configured for current loop operation to the standard 0 to 5 VDC output operation:

1. Turn off power to the analyzer.

2. If a recording device was connected to the output being modified, disconnect it.

3. Remove the top cover

    - Remove the set screw located in the top, center of the rear panel

    - Remove the screws fastening the top cover to the unit (four per side).

    - Lift the cover straight up.

4. Disconnect the current loop option PCA from the appropriate connector on the motherboard (refer to Figure 3-8).

5. Each connector, J19 and J23, requires two shunts. Place one shunt on the two left most pins and the second shunt on the two pins next to it (refer to Figure 3-8).

6. Reattach the top case to the analyzer.

The analyzer is now ready to have a voltage-sensing, recording device attached to that output.

Calibrate the analog output as described in Section 5.9.3

3.3.1.5. CONNECTING THE STATUS OUTPUTS

The status outputs report analyzer conditions via optically isolated NPN transistors, which sink up to 50 mA of DC current. These outputs can be used interface with devices that accept logic-level digital inputs, such as Programmable Logic Controllers (PLCs). Each status bit is an open collector output that can withstand up to 40 VDC. All of the emitters of these transistors are tied together and available at the "D" connector pin.

ATTENTION

COULD DAMAGE INSTRUMENT AND VOID WARRANTY

Most PLC's have internal provisions for limiting the current that the input will draw from an external device. When connecting to a unit that does not have this feature, an external dropping resistor must be used to limit the current through the transistor output to less than 50 mA. At 50 mA, the transistor will drop approximately 1.2V from its collector to emitter.

The status outputs are accessed via a 12-pin connector on the analyzer's rear panel labeled STATUS (Figure 3-9). Pin-outs for this connector are presented in Table 3-7.
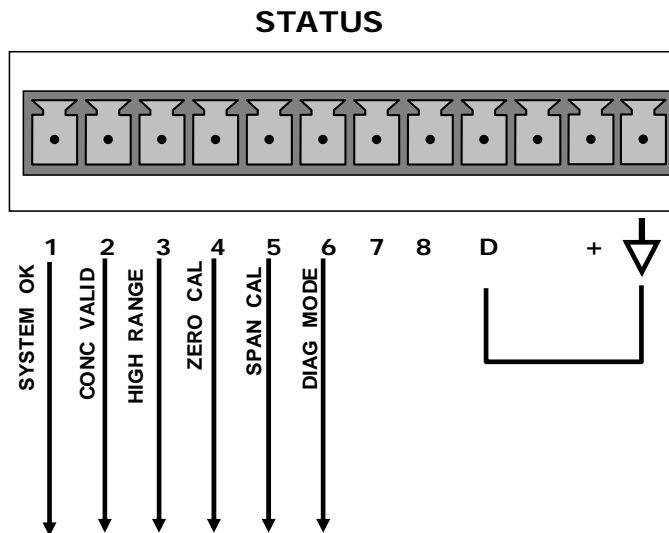
STATUS

Figure 3-9: Status Output Connector

Table 3-7: Status Output Signals

REAR PANEL LABEL	STATUS DEFINITION	CONDITION
1	**SYSTEM OK**	ON if no faults are present.
2	**CONC VALID**	OFF any time the **HOLD OFF** feature is active, such as during calibration or when other faults exist possibly invalidating the current concentration measurement (example: sample flow rate is outside of acceptable limits). ON if concentration measurement is valid.
3	**HIGH RANGE**	ON if unit is in high range of either the DUAL or Auto range modes.
4	**ZERO CAL**	ON whenever the instrument's **ZERO** point is being calibrated.
5	**SPAN CAL**	ON whenever the instrument's **SPAN** point is being calibrated.
6	**DIAG MODE**	ON whenever the instrument is in **DIAGNOSTIC** mode
7&8	SPARE	
D	**EMITTER BUS**	The emitters of the transistors on pins 1-8 are bussed together.
	SPARE	
+	**DC POWER**	+ 5 VDC, 300 mA source (combined rating with Control Output, if used).
▽	Digital Ground	The ground level from the analyzer's internal DC power supplies

3.3.1.6. **CONNECTING THE CONTROL INPUTS**

If you wish to use the analyzer to remotely activate the zero and span calibration modes, several digital control inputs are provided through a 10-pin connector labeled **CONTROL IN** on the analyzer's rear panel.

There are two methods for energizing the control inputs. The internal +5V available from the pin labeled "+" is the most convenient method. However, if full isolation is required, an external 5 VDC power supply should be used.
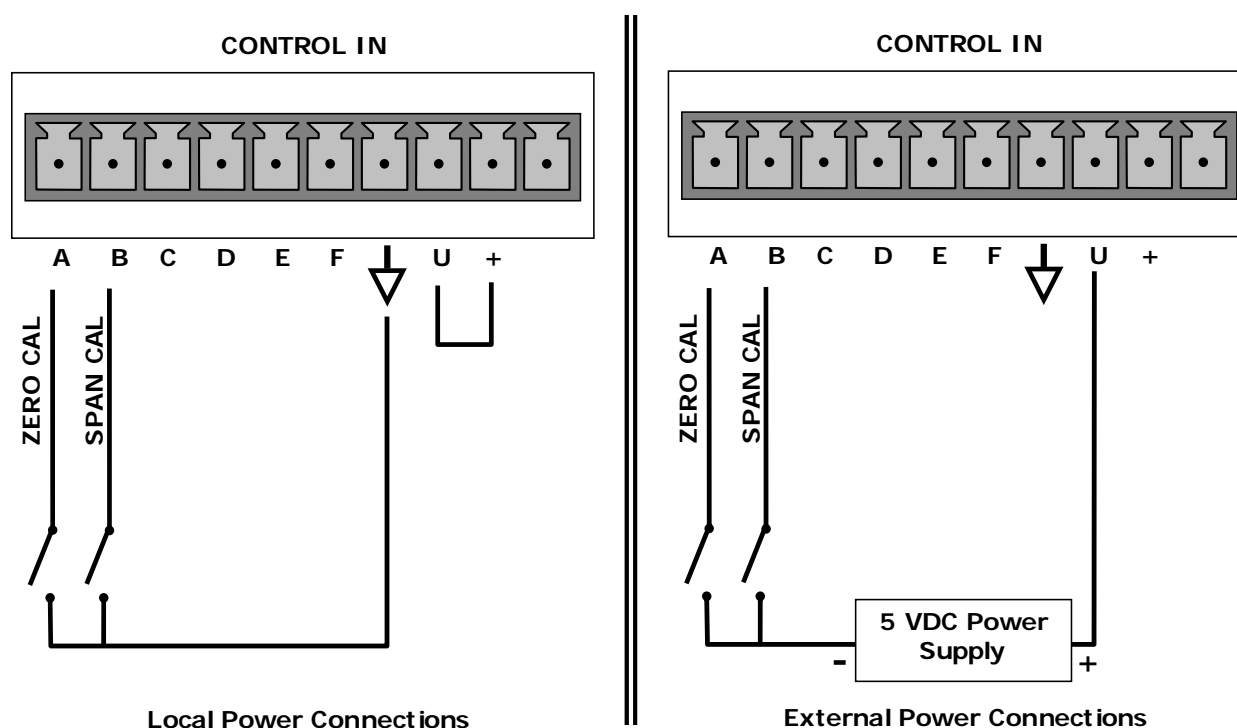
Figure 3-10:   Control Input Connector

Table 3-8: Control Input Signals

Input #	Status Definition	ON Condition
A	**REMOTE ZERO CAL**	The analyzer is placed in Zero Calibration mode. The mode field of the display will read **ZERO CAL R**.
B	**REMOTE SPAN CAL**	The analyzer is placed in span calibration mode as part of performing a low span (midpoint) calibration. The mode field of the display will read **LO CAL R**.
C, D, E & F	SPARE	
⏚	Digital Ground	The ground level from the analyzer's internal DC power supplies (same as chassis ground)
U	External Power input	Input pin for +5 VDC is required to activate pins A – F.
+	5 VDC output	Internally generated 5V DC power. To activate inputs A – F, place a jumper between this pin and the "U" pin. The maximum amperage through this port is 300 mA (combined with the analog output supply, if used).

3.3.1.7. **CONNECTING THE CONCENTRATION ALARM RELAY (OPTION 61)**

The concentration alarm option is comprised of four (4) "dry contact" relays on the rear panel of the instrument. This relay option is different from and in addition to the "Contact Closures" that come standard on all Teledyne API instruments. Each relay has 3 pins: Normally Open (NO), Common (C) and Normally Closed (NC).
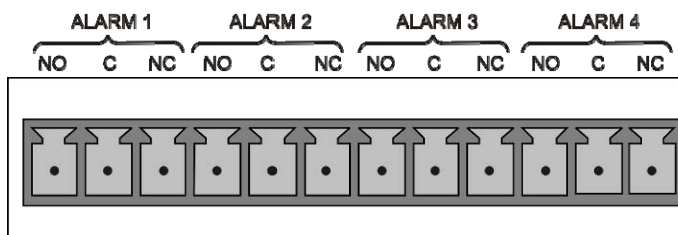
Figure 3-11:   **Concentration Alarm Relay**

Alarm 1   **"System OK 2"**

Alarm 2   **"Conc 1"**

Alarm 3   **"Conc 2"**

Alarm 4   **"Range Bit"**

"ALARM 1" RELAY

Alarm 1, which is "System OK 2" (system OK 1 is the status bit), is in the energized state when the instrument is "OK" and there are no warnings. If there is a warning active or if the instrument is put into the "DIAG" mode, Alarm 1 will change states. This alarm has "reverse logic" meaning that if you put a meter across the Common and Normally Closed pins on the connector you will find that it is OPEN when the instrument is OK. This is so that if the instrument should turn off or lose power, it will change states and you can record this with a data logger or other recording device.

"ALARM 2" RELAY & "ALARM 3" RELAY

Alarm 2 relay is associated with the "Concentration Alarm 1" set point in the software; Alarm 3 relay is associated with the "Concentration Alarm 2" set point in the software.

Alarm 2 Relay SO_2 Alarm 1 = xxx PPM

Alarm 3 Relay SO_2 Alarm 2 = xxx PPM

Alarm 2 Relay SO_2 Alarm 1 = xxx PPM

Alarm 3 Relay SO_2 Alarm 2 = xxx PPM

Alarm 2 relay will be turned on any time the concentration value exceeds the set-point, and will return to its normal state when the concentration value returns below the concentration set-point.

Even though the relay on the rear panel is a NON-Latching alarm and resets when the concentration goes back below the alarm set point, the warning on the front panel of the instrument will remain latched until it is cleared. You can clear the warning on the front panel either manually by pressing the CLR button on the front panel touch-screen or remotely through the serial port.

The software for this instrument is flexible enough to allow you to configure the alarms so that you can have two alarm levels for each concentration.

SO_2 Alarm 1 = 20 PPM

SO_2 Alarm 2 = 100 PPM

SO_2 Alarm 1 = 20 PPM

SO_2 Alarm 2 = 100 PPM

In this example, SO_2 Alarm 1 and SO_2 Alarm 1 will both be associated with the "Alarm 2" relay on the rear panel. This allows you to have multiple alarm levels for individual concentrations.

A more likely configuration for this would be to put one concentration on the "Alarm 1" relay and the other concentration on the "Alarm 2" relay.

SO_2 Alarm 1 = 20 PPM

SO_2 Alarm 2 = Disabled

SO_2 Alarm 1 = Disabled

SO_2 Alarm 2 = 100 PPM

"ALARM 4" RELAY

This relay is connected to the "range bit". If the instrument is configured for "Auto Range" and the reading goes up into the high range, it will turn this relay on.

3.3.1.8. CONNECTING THE COMMUNICATIONS INTERFACES

The T-Series analyzers are equipped with connectors for remote communications interfaces: **Ethernet**, **USB**, **RS-232**, **RS-232 Multidrop** and **RS-485**. In addition to using the appropriate cables, each type of communication method, must be configured using the SETUP>COMM menu, Section 6. Although Ethernet is DHCP-enabled by default, it can also be configured manually (Section 6.5.1) to set up a static IP address, which is the recommended setting when operating the instrument via Ethernet.

ETHERNET CONNECTION

For network or Internet communication with the analyzer, connect an Ethernet cable from the analyzer's rear panel Ethernet interface connector to an Ethernet port. Please refer to Section 6.5 for a description of the default configuration and setup instructions.

Configuration: Section 6.5

- manual configuration: Section 6.5.1

- automatic configuration (default): Section 6.5.2

USB CONNECTION

For direct communication between the analyzer and a PC, connect a USB cable between the analyzer and desktop or laptop USB ports, and ensure that their baud rates match (Section 6.2.2).

Note

If this option is installed, the COM2 port cannot be used for anything other than Multidrop communication.

Configuration: Section 6.5.3

RS-232 CONNECTION

For **RS-232** communications with data terminal equipment (**DTE**) or with data communication equipment (**DCE**) connect either a DB9-female-to-DB9-female cable (Teledyne API part number WR000077) or a DB9-female-to-DB25-male cable (Option 60A, Section 1.4), as applicable, from the analyzer's rear panel RS-232 port to the device. Adjust the DCE-DTE switch (Figure 3-4) to select DTE or DCE as appropriate.

Configuration: Sections 5.7 and 6.3

IMPORTANT

IMPACT ON READINGS OR DATA
Cables that appear to be compatible because of matching connectors may incorporate internal wiring that makes the link inoperable. Check cables acquired from sources other than Teledyne API for pin assignments (Figure 3-12) before using.

RS-232 COM PORT CONNECTOR PIN-OUTS
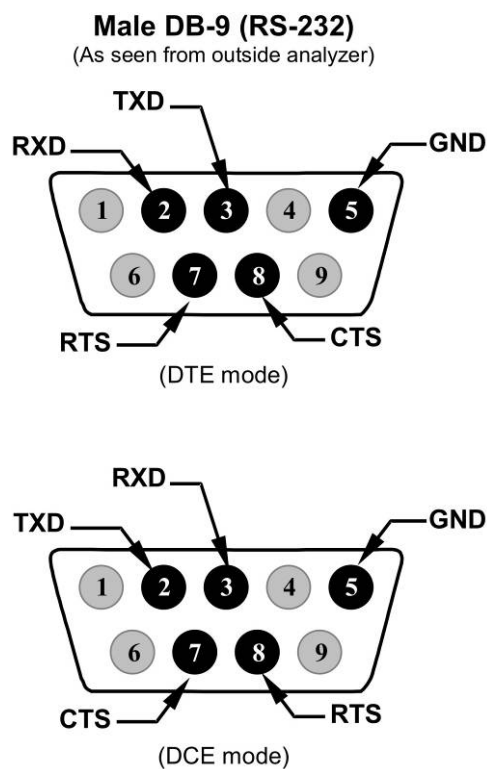
Figure 3-12:   Rear Panel Connector Pin-Outs for RS-232 Mode

The signals from these two connectors are routed from the motherboard via a wiring harness to two 10-pin connectors on the CPU card, J11 and J12 (Figure 3-13).
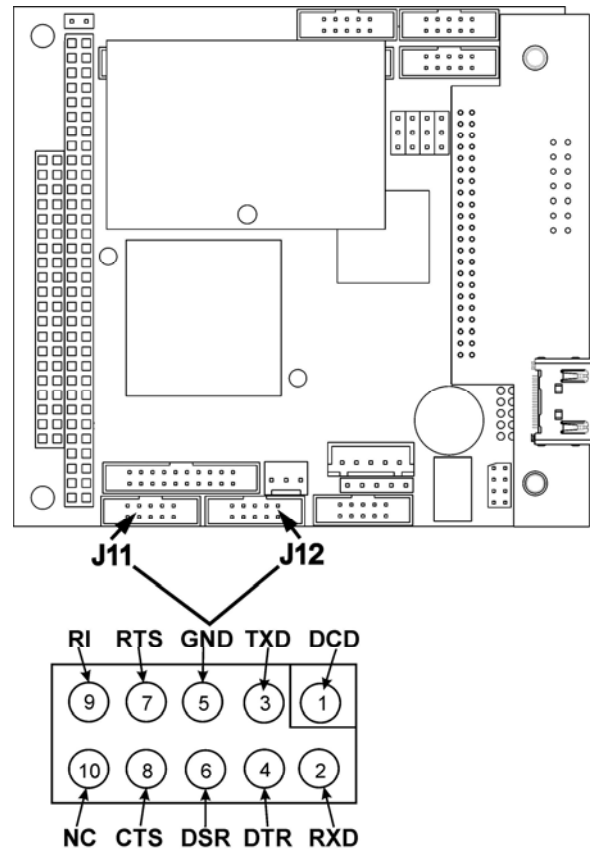
Figure 3-13:   Default Pin Assignments for CPU Com Port Connector (RS-232)

RS-232 COM PORT DEFAULT SETTINGS

As received from the factory, the analyzer is set up to emulate a DCE (Section 6.1) or modem, with Pin 3 of the DB-9 connector designated for receiving data and Pin 2 designated for sending data.

RS-232: RS-232 (fixed) DB-9 male connector

- Baud rate: 115200 bits per second (baud)

- Data Bits: 8 data bits with 1 stop bit

- Parity: None

COM2: RS-232 (configurable to RS 485), DB-9 female connector.

- Baud rate:19200 bits per second (baud).

- Data Bits: 8 data bits with 1 stop bit.

- Parity: None.

Configuration: Section 6.3

RS-232 MULTIDROP (OPTION 62) CONNECTION

When the RS-232 Multidrop option is installed, the instrument designated as last in the chain must be terminated. This requires installing a shunt between two pins on the multidrop printed circuit assembly (PCA) inside the instrument. Step-by-step instructions for installation follow.

Note	**Because the RS-232 Multidrop option uses both the RS232 and COM2 DB9 connectors on the analyzer's rear panel to connect the chain of instruments, COM2 port is no longer available for separate RS-232 or RS-485 operation.**

ATTENTION	**COULD DAMAGE INSTRUMENT AND VOID WARRANTY** **Printed Circuit Assemblies (PCAs) are sensitive to electro-static discharges too small to be felt by the human nervous system. Failure to use ESD protection when working with electronic assemblies will void the instrument warranty. Refer to Section 13 for more information on preventing ESD damage.**

To install shunt in the last analyzer:

1. With **NO power** to the instrument, remove its top cover and lay the rear panel open for access to the multidrop PCA, which is seated on the CPU.

2. On the multidrop PCA's JP2 connector, use the shunt provided to jumper Pins 21 ↔ 22 as indicated in (Figure 3-14).
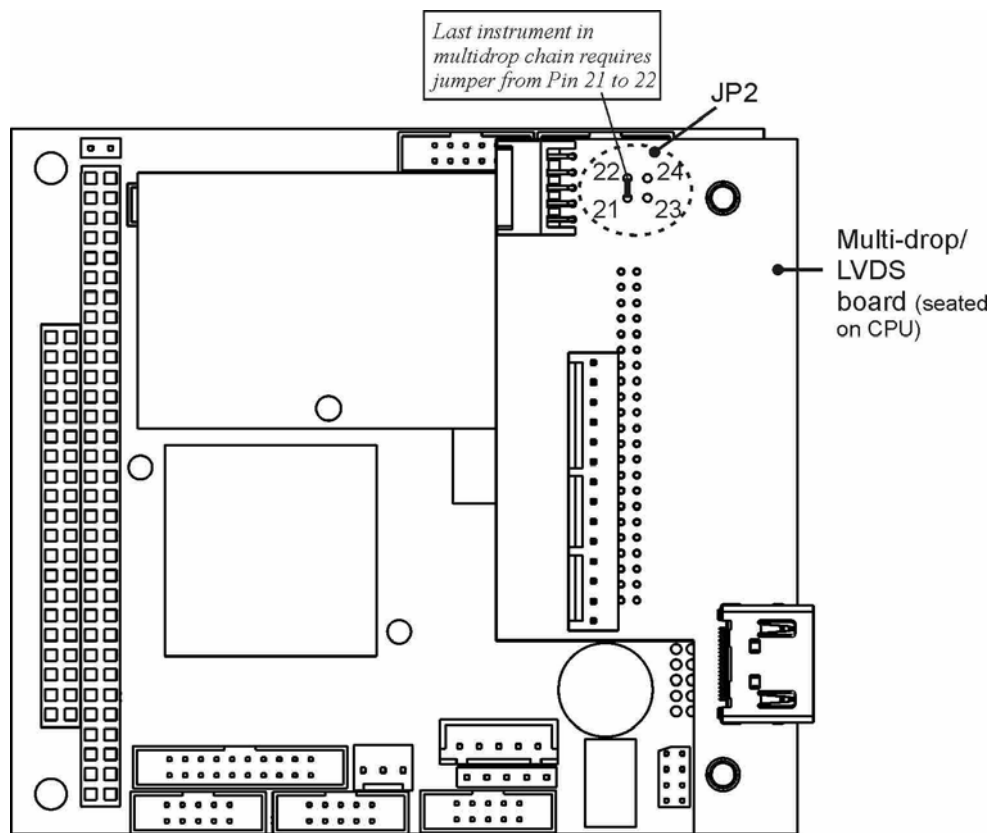
Figure 3-14:   JP2 Pins 21-22 on RS-232-Multidrop PCA

Note: If you are adding an instrument to the end of a previously configured chain, remove the shunt between Pins 21 ↔ 22 of JP2 on the Multidrop/LVDS PCA in the instrument that was previously the last instrument in the chain.

3. Close the instrument.

4. Referring to Figure 3-15 use straight-through DB9 male → DB9 female cables to interconnect the host RS232 port to the first analyzer's RS232 port; then from the first analyzer's COM2 port to the second analyzer's RS232 port; from the second analyzer's COM2 port to the third analyzer's RS232 port, etc., connecting in this fashion up to eight analyzers, subject to the distance limitations of the RS-232 standard.

5. BEFORE communicating from the host, power on the instruments and check that the Machine ID code is unique for each (Section 5.7.1). On the front panel menu, use SETUP>MORE>COMM>ID. Note that the default ID is typically the model number; to change the 4-digit identification number, press the button of the digit to be changed).

Note   **Teledyne API recommends setting up the first link, between the Host and the first analyzer, and testing it before setting up the rest of the chain.**
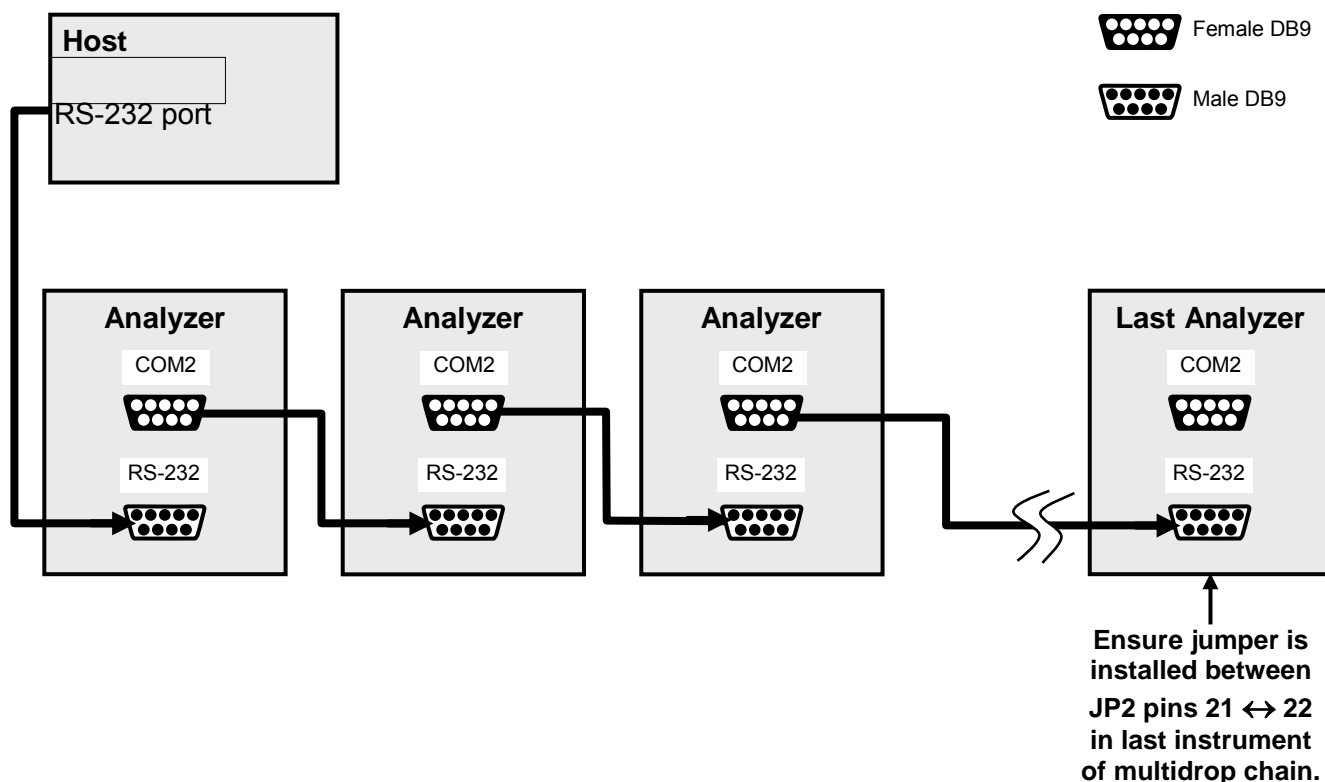
Figure 3-15:   RS-232-Multidrop PCA Host/Analyzer Interconnect Diagram

RS-485 CONNECTION

As delivered from the factory, COM2 is configured for RS-232 communications. This port can be reconfigured for operation as a non-isolated, half-duplex RS-485 port. Using COM2 for RS-485 communication disables the USB port. To reconfigure this port for RS-485 communication, please contact the factory.

3.3.2. PNEUMATIC CONNECTIONS

This section provides not only pneumatic connection information, but also important information about the gases required for accurate calibration (Section 3.3.2.10); it also illustrates the pneumatic layouts for the analyzer in its basic configuration and with options.

Before making the pneumatic connections, carefully note the following cautionary and additional messages:

⚠️	**CAUTION** **GENERAL SAFETY HAZARD** **SULFUR DIOXIDE (SO₂) IS A TOXIC GAS.** **DO NOT vent calibration gas and sample gas into enclosed areas. Obtain a Material Safety Data Sheet (MSDS) for this material. Read and rigorously follow the safety guidelines described there.**

	CAUTION **GENERAL SAFETY HAZARD**
⚠️	**Sample and calibration gases should only come into contact with PTFE (Teflon) or glass tubes and fixtures.** **They SHOULD NOT come in contact with brass or stainless steel fittings prior to the reaction cell.** **The exhaust from the analyzer's internal pump MUST be vented outside the immediate area or shelter surrounding the instrument.** **It is important to conform to all safety requirements regarding exposure to SO2.**

ATTENTION

COULD DAMAGE INSTRUMENT AND VOID WARRANTY

Maximum Pressure:
  Ideally the maximum pressure of any gas at the sample inlet should equal ambient atmospheric pressure and should NEVER exceed 1.5 in-hg above ambient pressure.

Venting Pressurized Gas:
  In applications where any gas (span gas, zero air supply, sample gas is) received from a pressurized manifold, a vent must be provided to equalize the gas with ambient atmospheric pressure before it enters the analyzer to ensure that the gases input do not exceed the maximum inlet pressure of the analyzer, as well as to prevent back diffusion and pressure effects. These vents should be:
  • **at least 0.2m long**
  • **no more than 2m long**
  • **vented outside the shelter or immediate area surrounding the instrument.**

Dust Plugs:
  Remove dust plugs from rear panel exhaust and supply line fittings before powering on/operating instrument. These plugs should be kept for reuse in the event of future storage or shipping to prevent debris from entering the pneumatics.

IMPORTANT

EPA Requirements:
  US EPA requirements state that zero air and span gases must be supplied at twice the instrument's specified gas flow rate. Therefore, the T100 zero and span gases should be supplied to their respective inlets in excess of 1300 cc^3/min (650 cc^3/min. x 2).

| IMPORTANT | ‑
Leak Check:
   Run a leak check once the appropriate pneumatic connections have been made; check all pneumatic fittings for leaks using the procedures defined in Section 11.3.6.
‑ |

CAUTION – GENERAL SAFETY HAZARD

Gas flow though the analyzer must be maintained at all time for units with a permeation tube installed. Insufficient gas flow allows gas to build up to levels that will contaminate the instrument or present a safety hazard to personnel.

Section 3.3.2.1 provides external pneumatic connection instructions, and Table 3-9 provides links to the location of various internal pneumatic layout illustrations.

Table 3-9: Pneumatic Layout Reference

Pneumatic Layout	Section
Basic	3.3.2.2
Zero/Span Valves	3.3.2.3
Internal Zero/Span (IZS)	3.3.2.4
Basic with O2 Sensor	3.3.2.8
Basic with CO2 Sensor	3.3.2.9

3.3.2.1. BASIC CONNECTIONS INCLUDING W/SPAN GAS AND W/GAS DILUTION CALIBRATOR

Refer to Figure 3-4 and Table 3-3 while making the pneumatic connections as follows:

SAMPLE inlet
Connect ¼" gas line not more than 2 m long, from sample gas source to this inlet.

When no zero/span/shutoff valve options, also connect line from calibration gas source to this inlet, but only when a calibration operation is actually being performed.

EXHAUST outlet
Connect exhaust line made of PTEF tubing; minimum O.D ¼", to this fitting. The exhaust line should be no longer than 10 meters, and should lead outside the shelter or immediate area surrounding the instrument.

Figure 3-16 and Figure 3-17 illustrate pneumatic connections for two of the possible basic configurations.
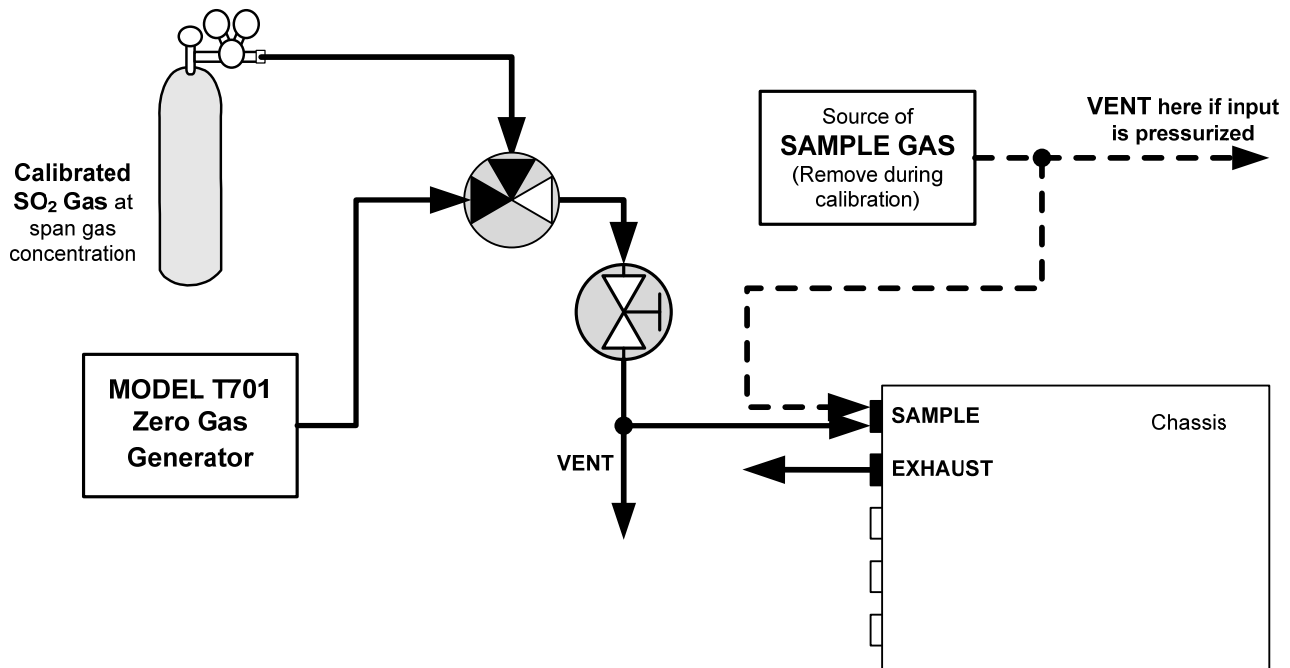
Figure 3-16:   **Pneumatic Connections–Basic Configuration–Using Bottled Span Gas**
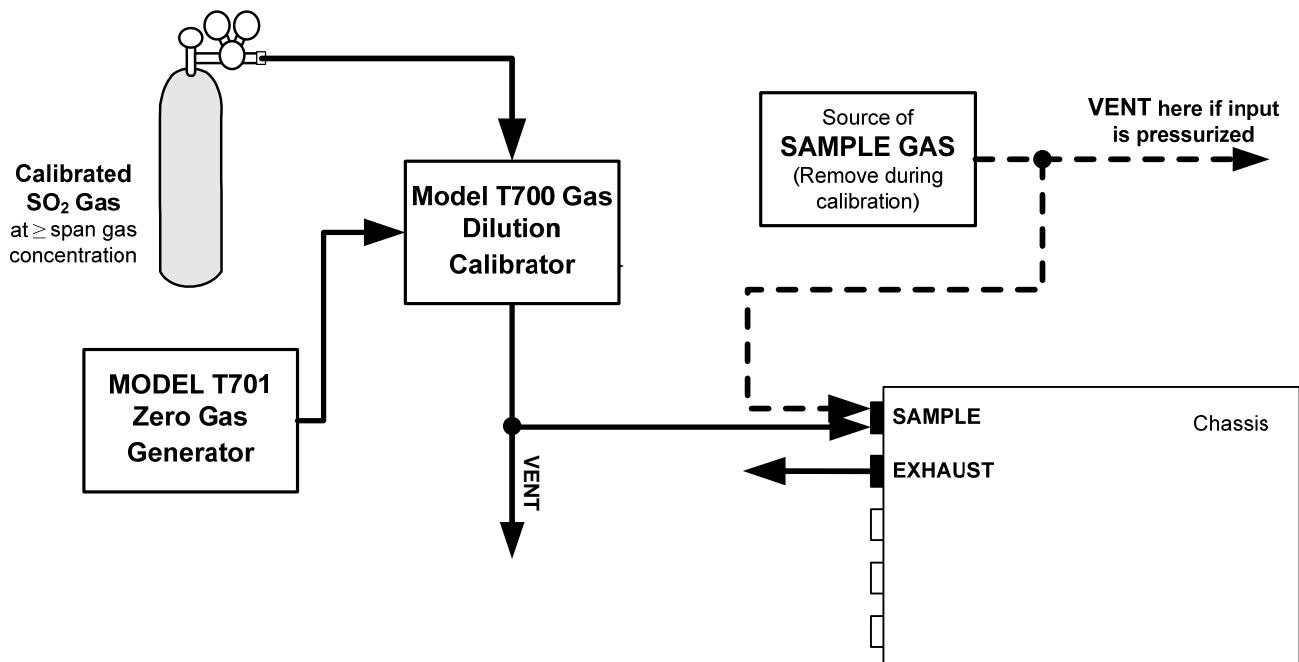
Figure 3-17:   **Pneumatic Connections–Basic Configuration–Using Gas Dilution Calibrator**

3.3.2.2. **PNEUMATIC LAYOUT FOR BASIC CONFIGURATION**
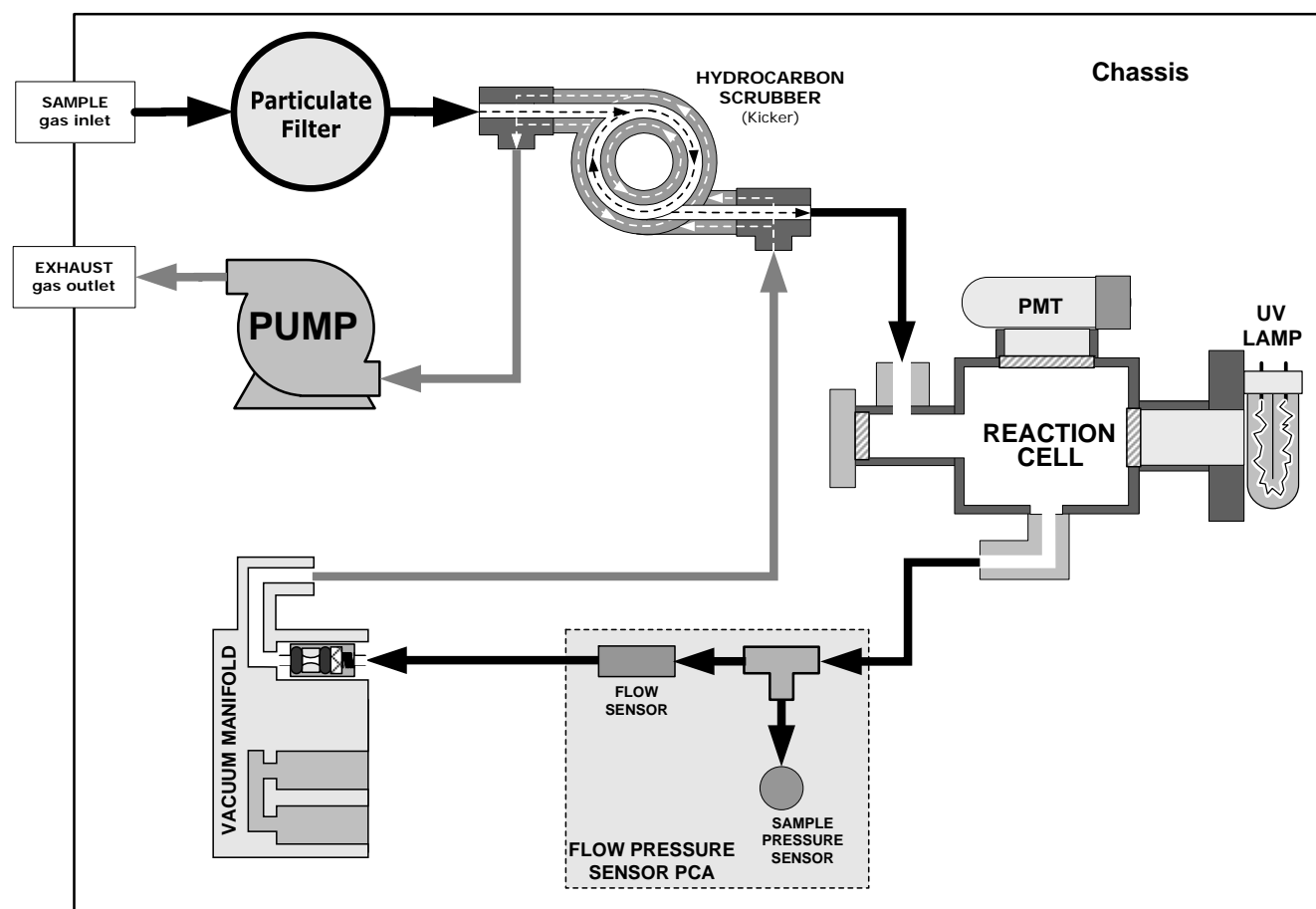
Figure 3-18:　T100 Gas Flow, Basic Configuration

3.3.2.3. **PNEUMATIC LAYOUT FOR ZERO/SPAN VALVES OPTION**

Figure 3-19 shows the internal, pneumatic connections for a T100 with the zero/span valve option installed.
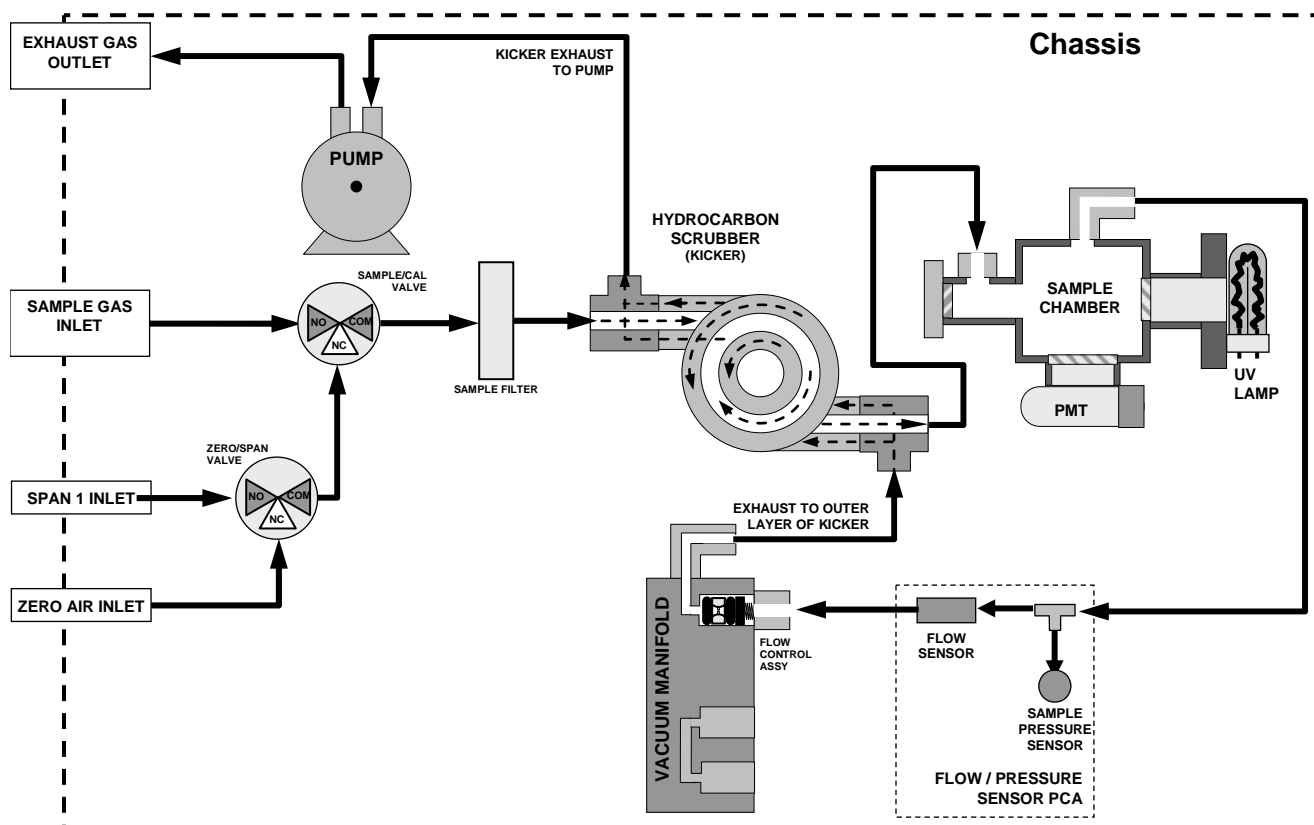
Figure 3-19:   Pneumatic Layout with Zero/Span Valves Option

Table 3-10 describes the state of each valve during the analyzer's various operational modes.

Table 3-10: Zero/Span and Sample/Cal Valve Operating States

MODE	VALVE	CONDITION
SAMPLE	Sample/Cal	Open to SAMPLE inlet
	Zero/Span	Open to ZERO AIR inlet
ZERO CAL	Sample/Cal	Open to zero/span inlet
	Zero/Span	Open to ZERO AIR inlet
SPAN CAL	Sample/Cal	Open to zero/span inlet
	Zero/Span	Open to SPAN GAS inlet

The state of the zero/span valves can also be controlled by any of the following means:

- manually from the analyzer's front panel by using the **SIGNAL I/O** controls located within the **DIAG** Menu (refer to Section 5.9.1)

- by activating the instrument's AutoCal feature (refer to Section 9.8)

- remotely by using the external digital control inputs (refer to Section 8.1.2 and Section 9.7.1)

- remotely through the RS-232/485 serial I/O ports (refer to Appendix A-6 for the appropriate commands)

Sources of zero and span gas must be capable of supplying at least 1.55 L/min. (maximum 2.5L/min). Both supply lines should be vented outside of the analyzer's enclosure. In order to prevent back-diffusion and pressure effects, these vent lines should be between 2 and 10 meters in length.

3.3.2.4. PNEUMATIC LAYOUT FOR INTERNAL ZERO/SPAN (IZS) GAS GENERATOR OPTION

Figure 3-20 shows the internal, pneumatic connections for the analyzer with the IZS option installed.
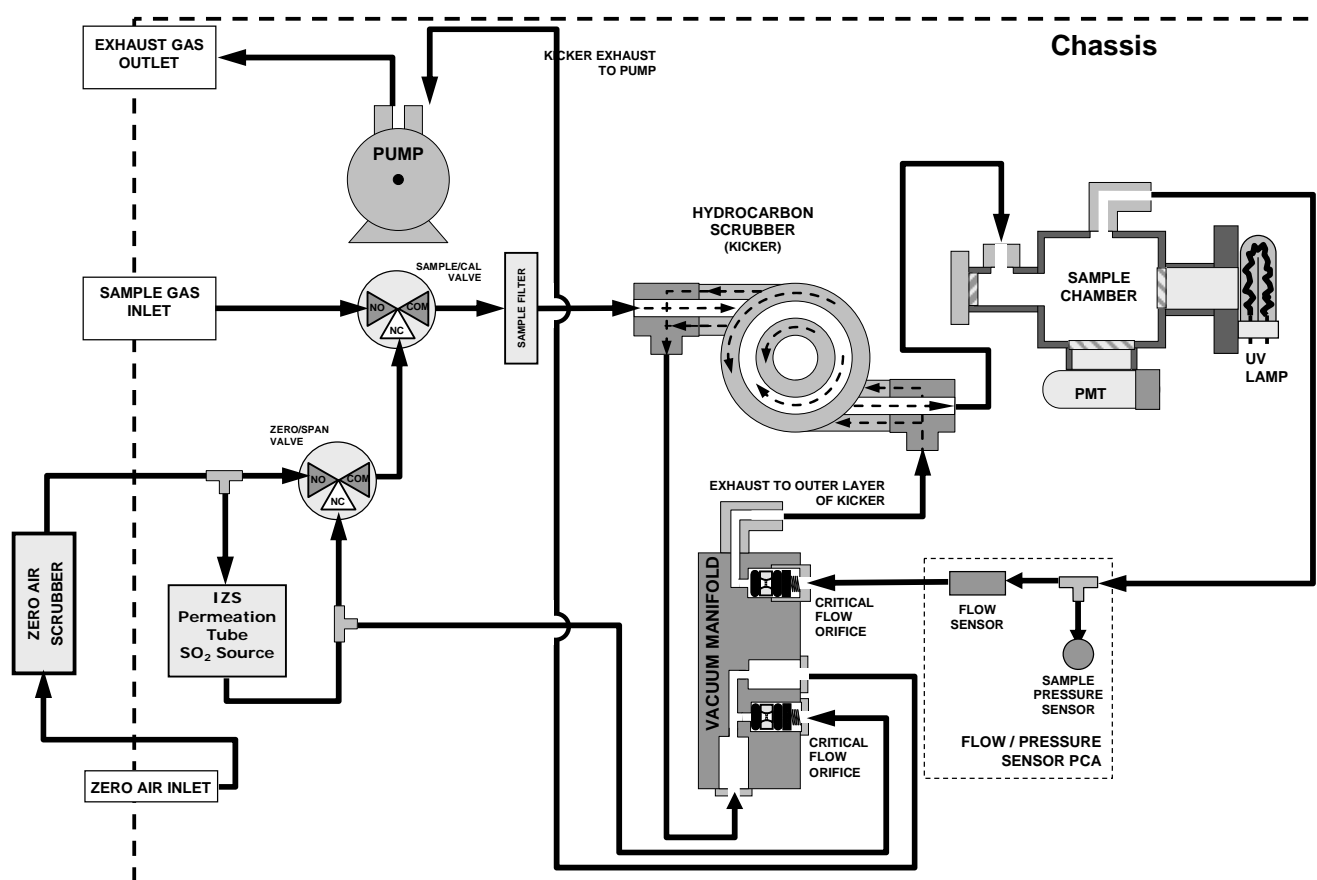
Figure 3-20:   Pneumatic Layout with IZS Options

The internal zero air and span gas generator (IZS) option includes a heated enclosure (Section 3.3.2.5) for a permeation tube (permeation tube must be purchased separately; see Section 1.4, in SO_2 IZS Permeation Tubes option), an external scrubber (Section 3.3.2.7) for producing zero air and a set of valves for switching between the sample gas inlet and the output of the zero/span subsystem, functionally very similar to the valves included in the zero/span valve option.

Table 3-11 describes the operational state of the valves associated with the IZS option during the analyzer's various operating modes.

Table 3-11: IZS Valve Operating States

MODE	VALVE	CONDITION
SAMPLE	Sample/Cal	Open to SAMPLE inlet
	Zero/Span	Open to ZERO AIR inlet
ZERO CAL	Sample/Cal	Open to zero/span valve
	Zero/Span	Open to ZERO AIR inlet
SPAN CAL	Sample/Cal	Open to zero/span valve
	Zero/Span	Open to SPAN GAS inlet

The state of the IZS valves can also be controlled by any of the following means:

- Manually from the analyzer's front panel by using the **SIGNAL I/O** controls under the **DIAG** Menu (refer to Section 5.9.1),

- By activating the instrument's AutoCal feature (refer to Section 9.8),

- Remotely by using the external digital control inputs (refer to Section 8.1.2 and Section 9.7.1),

- Remotely through the RS-232/485 serial I/O ports (refer to Appendix A-6 for the applicable commands), or

- Remotely via Ethernet

Note

The permeation tube is not included in the IZS Option and must be ordered separately. Refer to Section 1.4 for permeation tube options.

3.3.2.5. PERMEATION TUBE HEATER

In order to keep the permeation rate constant, the IZS enclosure is heated to a constant 50 C (10° above the maximum operating temperature of the instrument). The IZS heater is controlled by a precise PID (Proportional/Integral/Derivative) temperature control loop. A thermistor measures the actual temperature and reports it to the CPU for control feedback.

The IZS option includes an external zero air scrubber assembly that removes all SO_2 the zero air source. The scrubber is filled with activated charcoal.

3.3.2.6. SPAN GAS CONCENTRATION VARIATION

Span gas is created when zero air passes over a permeation tube containing liquid SO_2 under high pressure, which slowly permeates through a PTFE membrane into the surrounding air. The speed at which the SO_2 permeates the membrane is called the effusion rate. The concentration of the span gas is determined by three factors:

- Size of the membrane: The larger the area of the membrane, the more permeation occurs.

- Temperature of the SO_2: Increasing the temperature of the increases the pressure inside the tube and therefore increases the effusion rate.

- Flow rate of the zero air: If the previous two variables are constant, the permeation rate of air into the zero air stream will be constant. Therefore, a lower flow rate of

zero air produces higher concentrations of SO_2. The T100 usually has a constant flow rate and a constant permeation rate; hence, variations in concentration can be achieved by changing the IZS temperature.

3.3.2.7. EXTERNAL ZERO AIR SCRUBBER

The IZS option includes an external zero air scrubber assembly that removes all SO_2 from the zero air source. The scrubber is filled with activated charcoal.

3.3.2.8. PNEUMATIC LAYOUT WITH O₂ SENSOR OPTION

Figure 3-21 shows the internal, pneumatic connections for the analyzer with the oxygen (O_2) sensor option installed. Pneumatically, the O_2 sensor draws a flow of 80 cm³/min in addition to the normal sample flow rate. It is separately controlled with its own critical flow orifice.
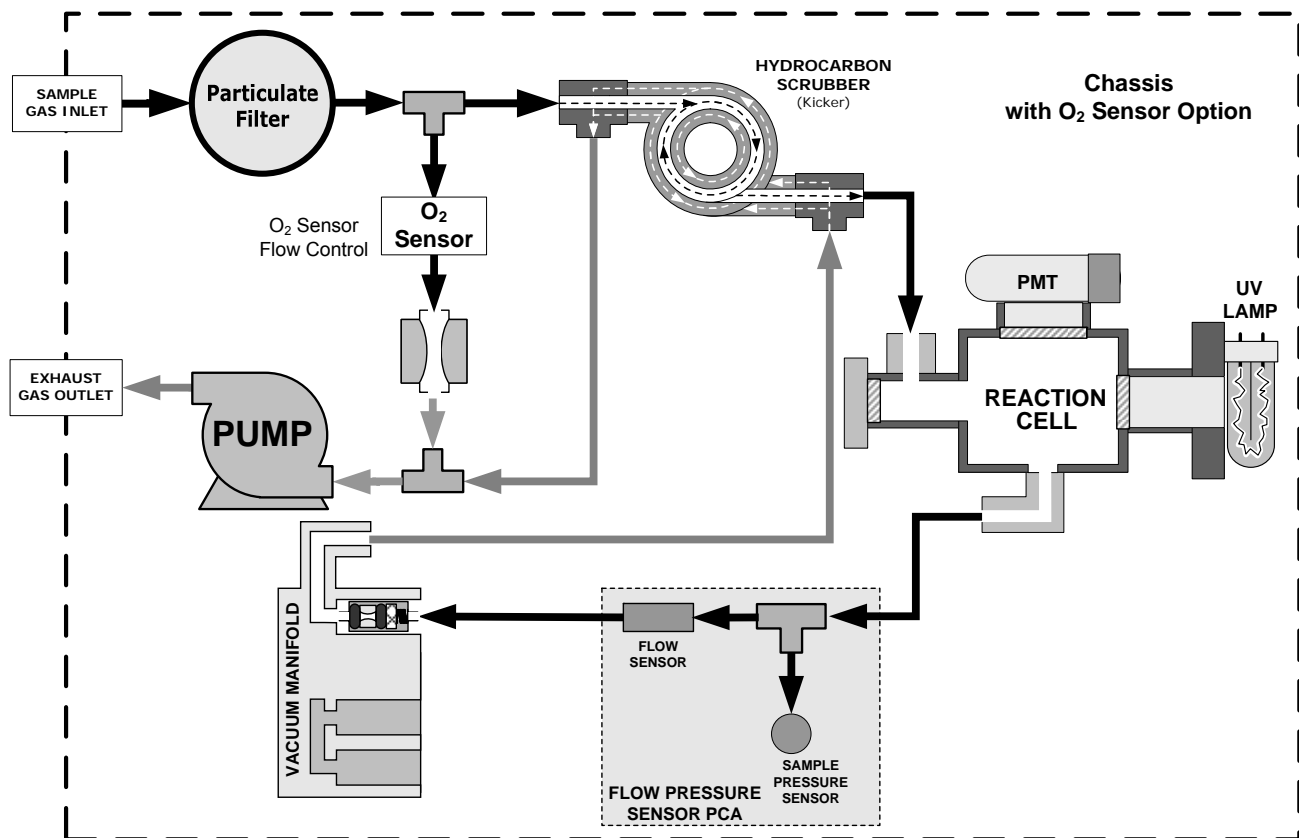
Figure 3-21:   Pneumatic Layout with O₂ Sensor

3.3.2.9. **PNEUMATIC LAYOUT WITH CO_2 SENSOR OPTION**

Figure 3-22 shows the internal, pneumatic connections for the analyzer with the carbon dioxide (CO_2) sensor option installed. Pneumatically, the CO_2 sensor is placed in line with the sample gas line between the particulate filter and the analyzer's sample chamber. It does not alter the gas flow rate of the sample through the analyzer.
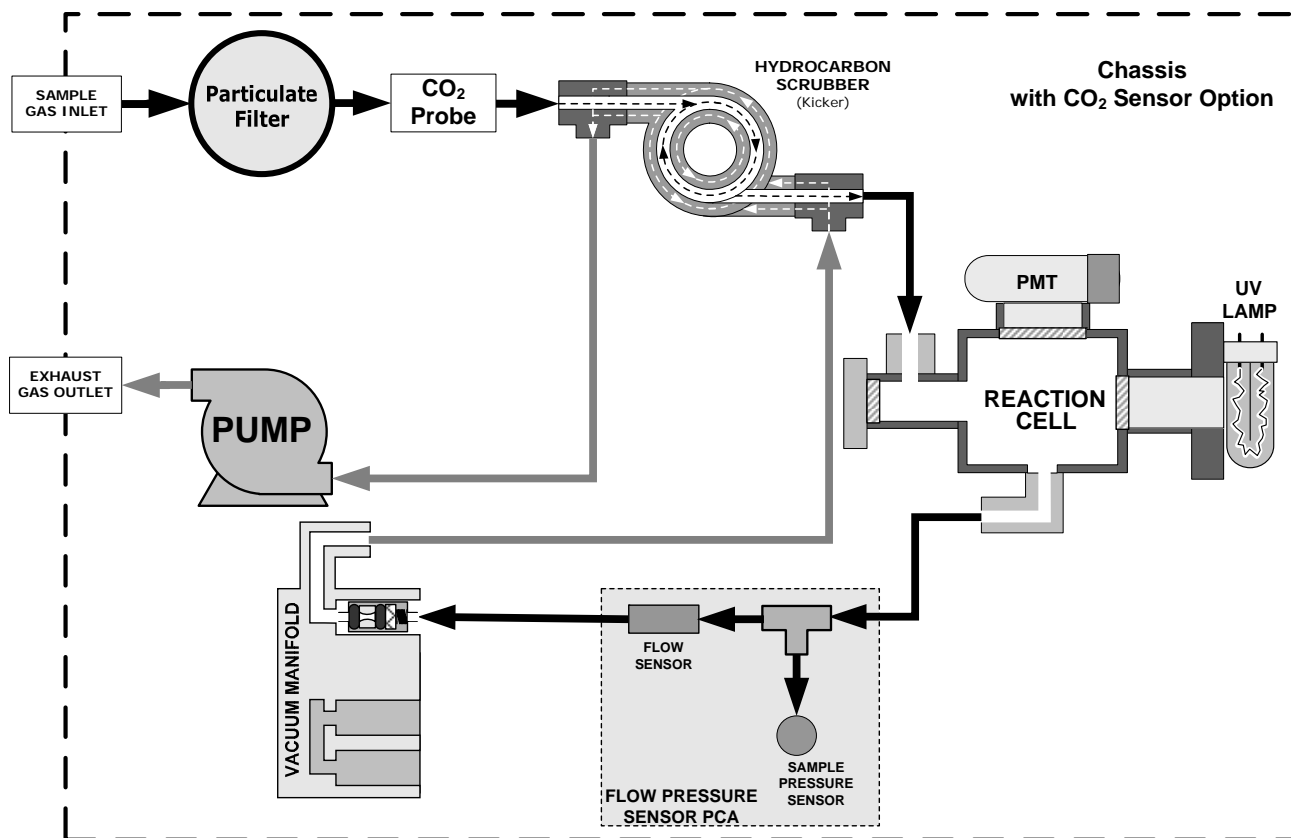
Figure 3-22:   **Pneumatic Layout with CO_2 Sensor**

3.3.2.10. **ABOUT ZERO AIR AND CALIBRATION (SPAN) GASES**

Zero air and span gas are required for accurate calibration.

ZERO AIR

A gas that is similar in chemical composition to the earth's atmosphere but without the gas being measured by the analyzer, in this case SO_2. If your analyzer is equipped with an Internal Zero Span (IZS) or an external zero air scrubber option, it is capable of creating zero air.

For analyzers without an IZS or external zero air scrubber option, a zero air generator such as the Teledyne API Model 701 can be used (Figure 3-16).

CALIBRATION (SPAN) GAS

Calibration gas is a gas specifically mixed to match the chemical composition of the type of gas being measured at near full scale of the desired measurement range. In this case, SO_2 measurements made with the Teledyne API T100 UV Fluorescence SO_2 Analyzer, it is recommended that you use a span gas with a SO_2 concentration equal to 80% of the measurement range for your application.

EXAMPLE: If the application is to measure between 0 ppm and 500 ppb, an appropriate span gas concentration would be 450 ppb SO_2.

Cylinders of calibrated SO_2 gas traceable to NIST-Standard Reference Material specifications (also referred to as SRM's or EPA protocol calibration gases) are commercially available. Table 3-12 lists specific NIST-SRM reference numbers for various concentrations of SO_2.

Table 3-12: NIST-SRM's Available for Traceability of SO$_2$ Calibration Gases

NIST-SRM	Type	Nominal Concentration
1693a	Sulfur dioxide in N_2	50 ppm
1694a	Sulfur dioxide in N_2	100 pp
1661a	Sulfur dioxide in N_2	500 ppm
2659a[1]	O_2 in N_2	21% by weight
2626a	CO_2 in N_2	4% by weight
2745[2]	CO_2 in N_2	16% by weight
[1] Used to calibrate optional O_2 sensor. [2] Used to calibrate optional CO_2 sensor.		

SPAN GAS FOR MULTIPOINT CALIBRATION

Some applications, such as EPA monitoring, require a multipoint calibration procedure where span gases of different concentrations are needed. We recommend using a bottle of calibrated SO_2 gas of higher concentration in conjunction with a gas dilution calibrator such as a Teledyne API Model T700 (Figure 3-17) This type of calibrator precisely mixes a high concentration gas with zero air (both supplied externally) to accurately produce span gas of the correct concentration. Linearity profiles can be automated with this model and run unattended over night.

3.4. STARTUP, FUNCTIONAL CHECKS, AND INITIAL CALIBRATION

If you are unfamiliar with the T100 principles of operation, we recommend that you read Section 13. For information on navigating the analyzer's software menus, refer to the menu trees provided in Appendix A.

	CAUTION - GENERAL SAFETY HAZARD
⚠️	**Do not look at the UV lamp while the unit is operating. UV light can cause eye damage. Always use safety glasses made from UV blocking material whenever working with the UV Lamp. (Generic plastic glasses are not adequate).**

3.4.1. STARTUP

After the electrical and pneumatic connections are made, an initial functional check is in order. Turn on the instrument. The pump and exhaust fan should start immediately. The display will show a momentary splash screen of the Teledyne API logo and other information during the initialization process while the CPU loads the operating system, the firmware and the configuration data.

The analyzer should automatically switch to Sample Mode after completing the boot-up sequence and start monitoring the gas. However, there is an approximately one hour warm-up period before reliable gas measurements can be taken. During the warm-up period, the front panel display may show messages in the Parameters field.

3.4.2. WARNING MESSAGES

Because internal temperatures and other conditions may be outside the specified limits during the analyzer's warm-up period, the software will suppress most warning conditions for 30 minutes after power up. If warning messages persist after the 60 minutes warm up period is over, investigate their cause using the troubleshooting guidelines in Section 12.1.1.

To view and clear warning messages, press:
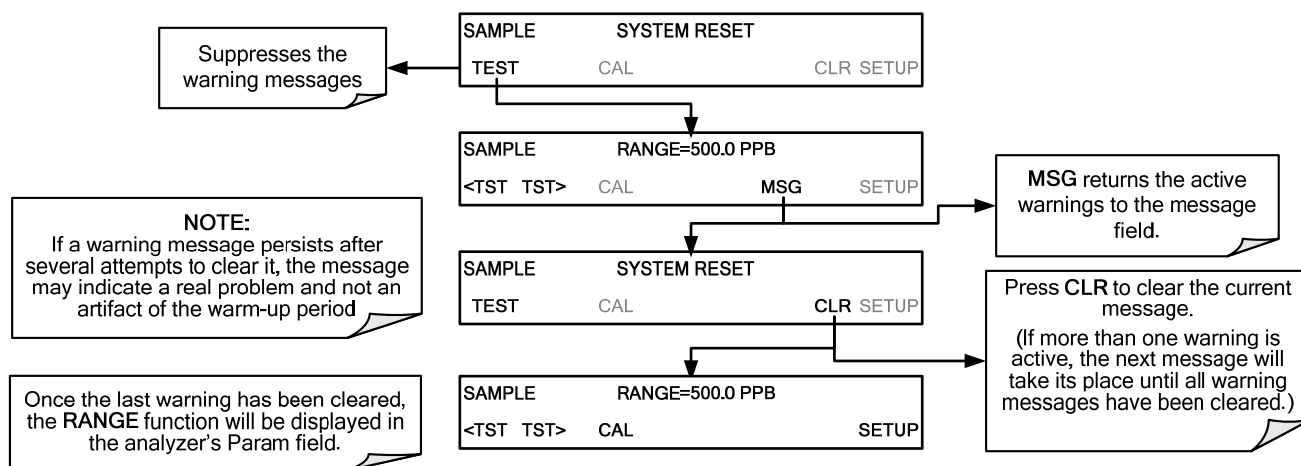
Figure 3-23:   Warning Messages

Table 3-13 lists brief descriptions of the warning messages that may occur during start up for T100 analyzers with no options installed.

Table 3-13:   Possible Startup Warning Messages – T100 Analyzers w/o Options

Message	Meaning
ANALOG CAL WARNING	The instrument's A/D circuitry or one of its analog outputs is not calibrated.
BOX TEMP WARNING	The temperature inside the T100 chassis is outside the specified limits.
CANNOT DYN SPAN[2]	Remote span calibration failed while the dynamic span feature was set to turned on.
CANNOT DYN ZERO[3]	Remote zero calibration failed while the dynamic zero feature was set to turned on.
CONFIG INITIALIZED	Configuration was reset to factory defaults or was erased.
DARK CAL WARNING	Dark offset above limit specified indicating that too much stray light is present in the sample chamber.
DATA INITIALIZED	DAS data storage was erased.
HVPS WARNING	High voltage power supply for the PMT is outside of specified limits.
PMT DET WARNING	PMT detector output is outside of operational limits.
PMT TEMP WARNING	PMT temperature is outside of specified limits.
RCELL TEMP WARNING	Sample chamber temperature is outside of specified limits.
REAR BOARD NOT DET	CPU unable to communicate with motherboard.
RELAY BOARD WARN	CPU is unable to communicate with the relay PCA.
SAMPLE FLOW WARN	The flow rate of the sample gas is outside the specified limits.
SAMPLE PRESS WARN	Sample gas pressure outside of operational parameters.
SYSTEM RESET[1]	The computer was rebooted.
UV LAMP WARNING	The UV lamp intensity measured by the reference detector reading too low or too high.

[1] Clears 45 minutes after power up.

[2] Clears the next time successful zero calibration is performed.

[3] Clears the next time successful span calibration is performed.

Table 3-14 lists brief descriptions of the warning messages that may occur during start up for T100 analyzers with optional second gas options or alarms installed.

Table 3-14:   Possible Startup Warning Messages – T100 Analyzers with Options

Message	Meaning
O2 CELL TEMP WARN[1]	O_2 sensor cell temperature outside of warning limits specified by *O2_CELL_SET* variable.
IZS TEMP WARNING[2]	On units with IZS options installed: The permeation tube temperature is outside of specified limits.
O2 ALARM 1 WARN[1, 4]	O_2 Alarm limit #1 has been triggered.[4]
O2 ALARM 2 WARN[1, 4]	O_2 Alarm limit #2 has been triggered.[4]
CO2 ALARM 1 WARN[3, 4]	CO_2 Alarm limit #1 has been triggered.[4]
CO2 ALARM 2 WARN[3, 4`]	CO_2 Alarm limit #2 has been triggered.[4]
SO2 ALARM1 WARN[4]	SO_2 Alarm limit #1 has been triggered.[4]
SO2 ALARM2 WARN[4]	SO_2 Alarm limit #2 has been triggered.[4]

[1] Only appears when the optional O_2 sensor is installed.
[2] Only appears when the optional internal zero span (IZS) option is installed.
[3] Only appears when the optional CO_2 sensor is installed.
[4] Only Appears when the optional gas concentration alarms are installed

3.4.3. FUNCTIONAL CHECKS

After the analyzer's components have warmed up for at least 60 minutes, verify that the software properly supports any hardware options that were installed.

For information on navigating through the analyzer's software menus, refer to the menu trees described in Appendix A.1.

Check to ensure that the analyzer is functioning within allowable operating parameters.

- Appendix C includes a list of test functions viewable from the analyzer's front panel as well as their expected values.

- These functions are also useful tools for diagnosing performance problems with your analyzer (refer to Section 12.1.2).

- The enclosed Final Test and Validation Data Sheet (P/N 04551) lists these values before the instrument left the factory.

To view the current values of these parameters press the following control button sequence on the analyzer's front panel. Remember until the unit has completed its warm up these parameters may not have stabilized.
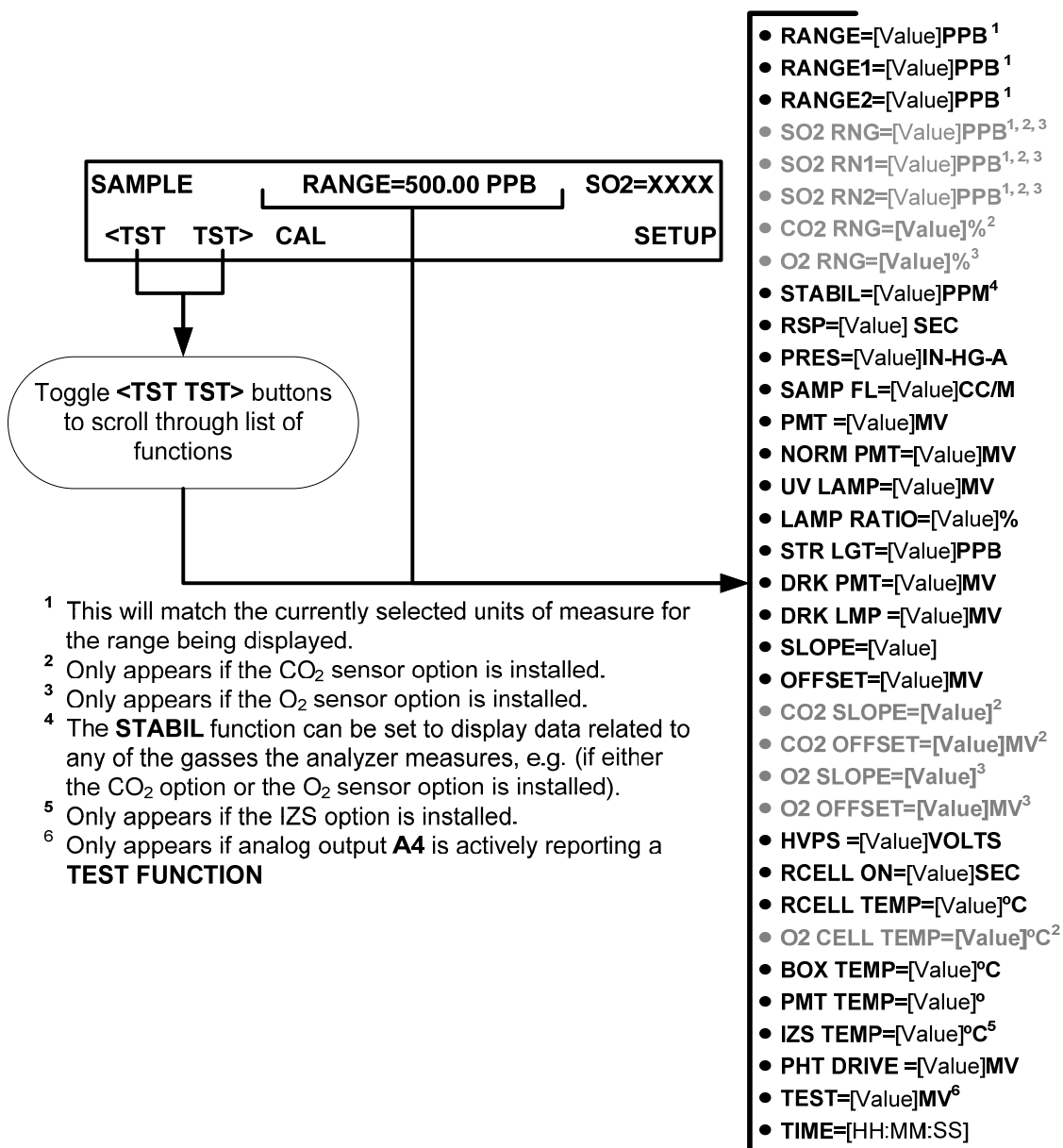
Figure 3-24:   Functional Check

3.4.4. INITIAL CALIBRATION

To perform the following calibration you must have sources for zero air and span gas available for input into the sample port on the back of the analyzer. Refer to Section 3.3.2 for instructions for connecting these gas sources.

The initial calibration should be carried out using the same reporting range set up as used during the analyzer's factory calibration. This will allow you to compare your calibration results to the factory calibration as listed on the *Final Test and Validation Data Sheet*, P/N 04551.

If both available DAS parameters for a specific gas type are being reported via the instruments analog outputs (e.g. **CONC1** and **CONC2** when the **DUAL** range mode is activated), separate calibrations should be carried out for each parameter.

- Use the **LOW** button when calibrating for **CONC1** (equivalent to **RANGE1**).

- Use the **HIGH** button when calibrating for **CONC2** (equivalent to **RANGE2**).

Refer to the Configurable Analog Output Addendum, P/N 06270 for more information on the configurable analog output reporting ranges.

| Note | **The following procedure assumes that the instrument does not have any of the available Valve Options installed. Refer to Section 9.4 for instructions for calibrating instruments possessing valve options** |

| Note | **The T100 analyzer has been tested for its ability to reject interference for most sources. See Section 13.1.9 for more information on this topic.** |

3.4.4.1. INITIAL CALIBRATION PROCEDURE FOR BASIC ANALYZERS (NO 2ND GAS OPTION)

The following procedure assumes that:

- The instrument DOES NOT have any of the available calibration valve or gas inlet options installed;

- Cal gas will be supplied through the SAMPLE gas inlet on the back of the analyzer (refer to Figure 3-4), and;

- The pneumatic setup matches that described in Section 3.3.2.

VERIFYING THE REPORTING RANGE SETTINGS

While it is possible to perform the following procedure with any range setting we recommend that you perform this initial checkout using following reporting range settings:

- Unit of Measure: PPB

- Analog Output Reporting Range: 500.0 ppb

- Mode Setting: SNGL

While these are the default settings for the T100 analyzer, it is recommended that you verify them before proceeding with the calibration procedure, by pressing:

```
SAMPLE        RANGE=500.0 PPB       SO2= XXXX
  <TST  TST>  CAL                       SETUP
```

```
SETUP            PRIMARY SETUP MENU
  CFG  DAS  RNGE PASS  CLK  MORE         EXIT
```

```
SETUP            RANGE CONTROL MENU
  MODE SET  UNIT                         EXIT
```

Verify that the **MODE** is set for **SNGL.**

If it is not, press **SINGL then ENTR**

```
SETUP            RANGE MODE:SNGL
  SNGL DUAL AUTO               ENTR  EXIT
```

```
SETUP            RANGE CONTROL MENU
  MODE SET  UNIT                         EXIT
```

Verify that the **RANGE** is set for **500.0**

If it is not, toggle each numeric button until the proper range is set, then press **ENTR**.

```
SETUP            RANGE: 500.0 Conc
   0    0    5    0    0    .0  ENTR  EXIT
```

```
SETUP            RANGE CONTROL MENU
  MODE SET  UNIT                         EXIT
```

Press **EXIT** 3x's to return the unit to the **SAMPLE** mode

Verify that the **UNIT**s is set for **PPM**

If it is not, press **PPM then ENTR**

```
SETUP            CONC UNITS:PPM
  PPB   PPM  UGM  MGM          ENTR  EXIT
```

Figure 3-25:   Reporting Range Verification

DILUTION RATIO SETUP

If the dilution ratio option is enabled on your T100 and your application involves diluting the sample gas before it enters the analyzer, set the dilution ration as follows:

SAMPLE   RANGE=500.0 PPB   SO2= XXXX

<TST   TST> CAL   **SETUP**

SETUP   **PRIMARY SETUP MENU**

 CFG DAS **RNGE** PASS CLK MORE   EXIT

SETUP   **RANGE CONTROL MENU**

 UNIT   **DIL**   EXIT

Toggle these buttons to set the dilution factor.

This is the number by which the analyzer will multiply the SO₂ concentration of the gas passing through the reaction cell.

SETUP   **CO DIL FACTOR:1.0 Gain**

0   0   0   0   1   .0   ENTR EXIT

EXAMPLE

SETUP   **CO DIL FACTOR 20.0 Gain**

0   0   0   2   0   .0   ENTR EXIT

Only appears if the optional CO₂ sensor is installed.

SETUP   **CO2 DIL FACTOR:1.0 Gain**

0   0   0   0   1   .0   **ENTR EXIT**

Only appears if the optional O₂ sensor is installed.

SETUP   **O2 DIL FACTOR:1.0 Gain**

0   0   0   0   1   .0   **ENTR EXIT**

EXIT ignores the new setting.

ENTR accepts the new setting.

Figure 3-26:   Dilution Ratio Setup

SET SO₂ SPAN GAS CONCENTRATION

Set the expected SO₂ span gas concentration. This should be 80% of the concentration range for which the analyzer's analog output range is set.
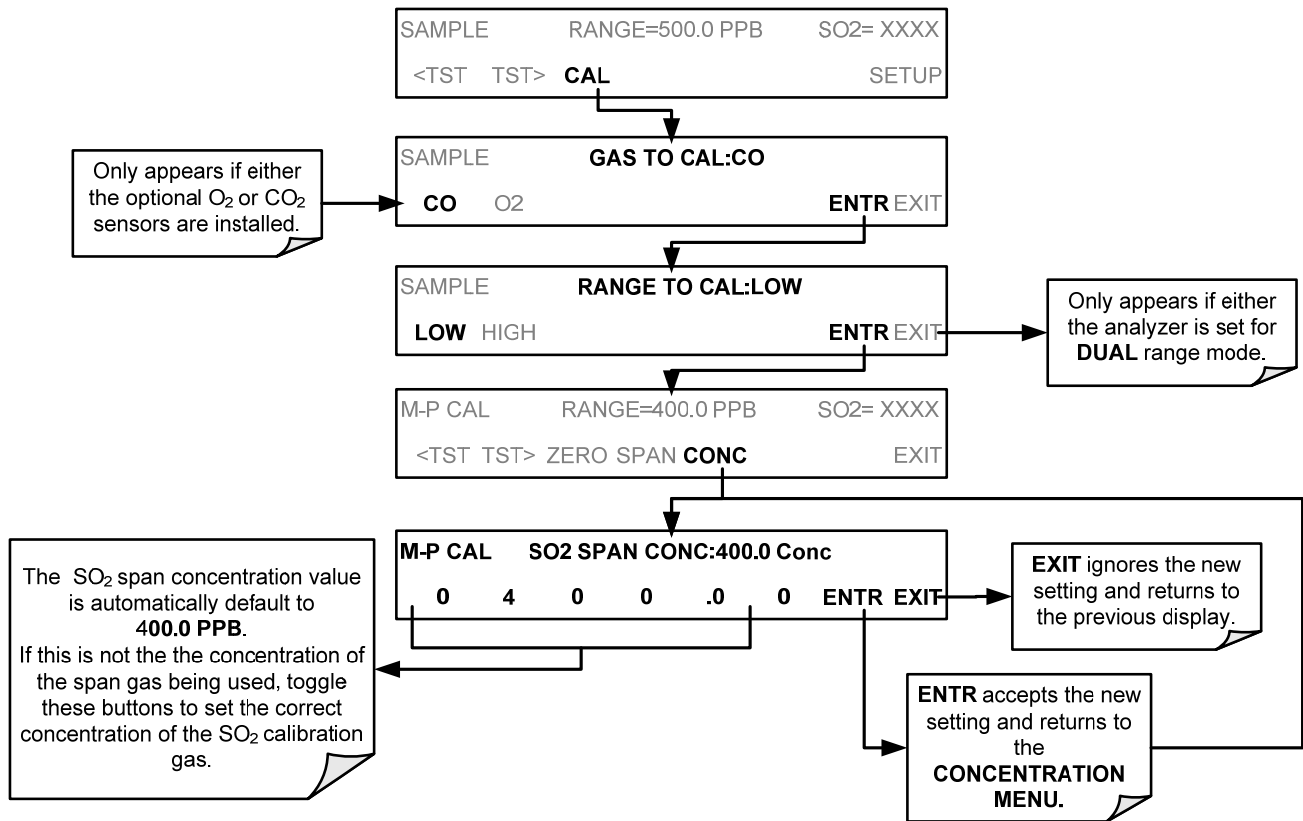
Figure 3-27:   SO₂ Span Gas Setting

ZERO/SPAN CALIBRATION

To perform the zero/span calibration procedure, press:
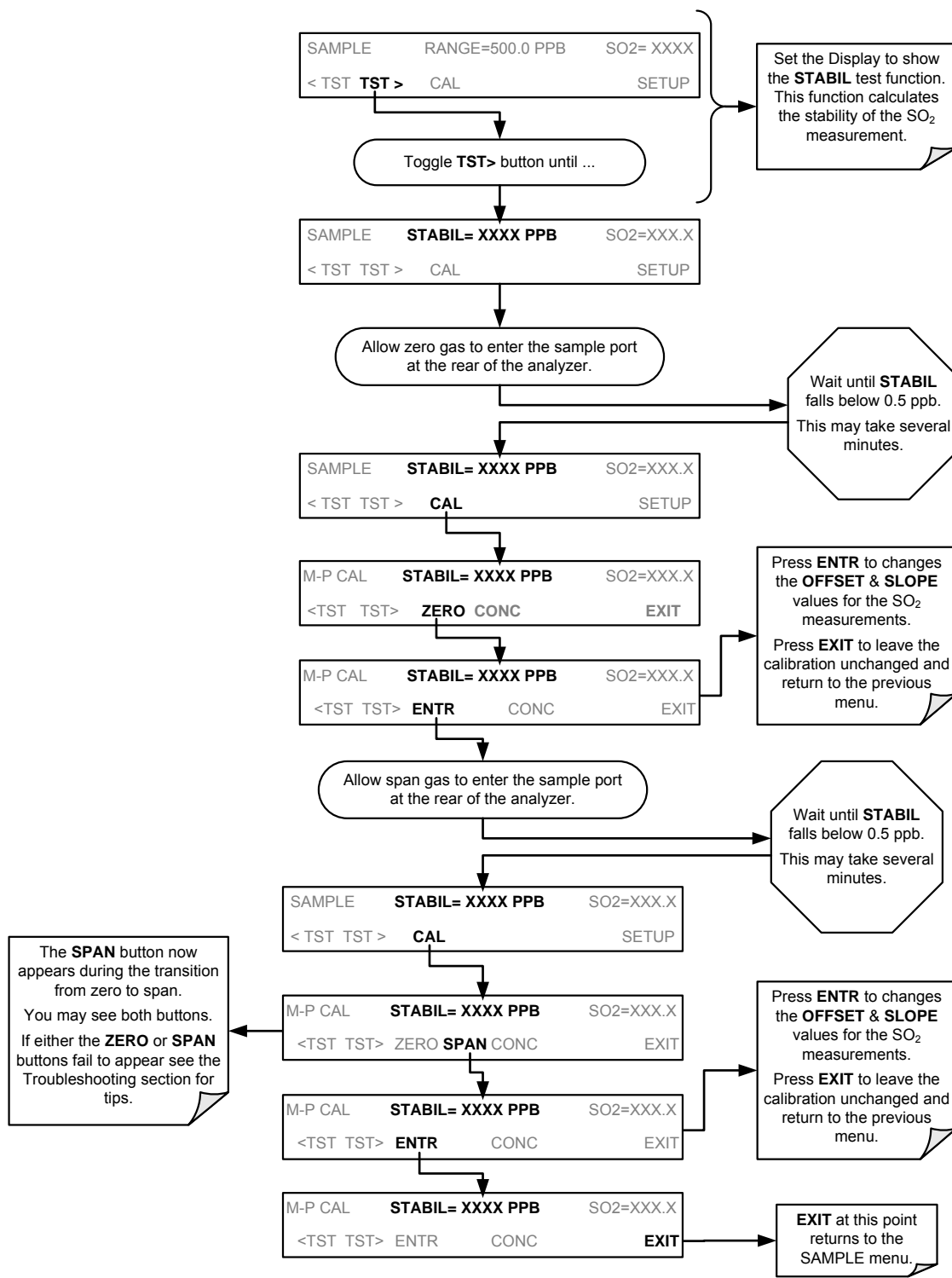
Figure 3-28:   Zero/Span Calibration Procedure

3.4.4.2. CALIBRATION PROCEDURE FOR THE O$_2$ OPTION

If your analyzer is equipped with the optional O$_2$ sensor, this sensor should be calibrated during installation of the instrument. Refer to Section 9.10.1 for instructions.

3.4.4.3. CALIBRATION PROCEDURE FOR THE CO$_2$ OPTION

If your analyzer is equipped with the optional CO$_2$ sensor, this sensor should be calibrated during installation of the instrument. Refer to Section 9.10.2 for instructions.

Note   **Once you have completed the above set-up procedures, please fill out the Quality Questionnaire that was shipped with your unit and return it to Teledyne API. This information is vital to our efforts in continuously improving our service and our products. THANK YOU.**

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PART II

OPERATING INSTRUCTIONS

4. OVERVIEW OF OPERATING MODES

To assist in navigating the analyzer's software, a series of menu trees can be found in Appendix A of this manual.

Note

> **Some control buttons on the touch screen do not appear if they are not applicable to the menu that you're in, the task that you are performing, the command you are attempting to send, or to incorrect settings input by the user. For example, the ENTR button may disappear if you input a setting that is invalid or out of the allowable range for that parameter, such as trying to set the 24-hour clock to 25:00:00. Once you adjust the setting to an allowable value, the ENTR button will re-appear.**

The T100 software has a variety of operating modes. Most commonly, the analyzer will be operating in SAMPLE mode. In this mode, a continuous read-out of the SO_2 concentration can be viewed on the front panel and output as an analog voltage from rear panel terminals, calibrations can be performed, and TEST functions and WARNING messages can be examined.

The second most important operating mode is SETUP mode. This mode is used for performing certain configuration operations, such as for the DAS system, the reporting ranges, or the serial (RS-232 / RS-485 / Ethernet) communication channels. The SET UP mode is also used for performing various diagnostic tests during troubleshooting.
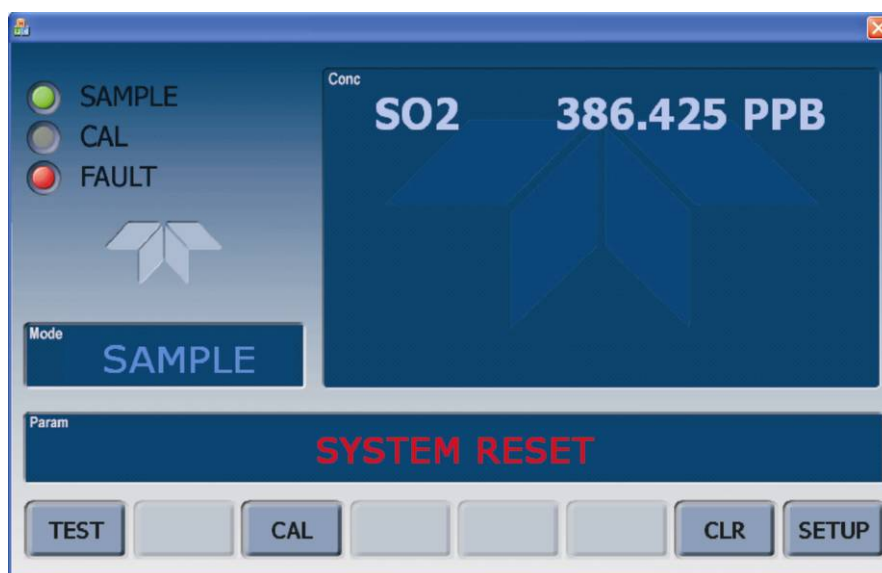
Figure 4-1: Front Panel Display

The Mode field of the front panel display indicates to the user which operating mode the unit is currently running.

In addition to **SAMPLE** and **SETUP**, other modes available are presented in Table 4-1.

Table 4-1: Analyzer Operating Modes

MODE	EXPLANATION
DIAG	One of the analyzer's diagnostic modes is active (refer to Section 5.9).
LO CAL A[1]	Unit is performing LOW SPAN (midpoint) calibration initiated automatically by the analyzer's AUTOCAL feature
LO CAL R[1]	Unit is performing LOW SPAN (midpoint) calibration initiated remotely through the COM ports or digital control inputs.
M-P CAL[1]	This is the basic calibration mode of the instrument and is activated by pressing the CAL button.
SAMPLE	Sampling normally, flashing text indicates adaptive filter is on.
SAMPLE A	Indicates that unit is in SAMPLE mode and AUTOCAL feature is activated.
SETUP	SETUP mode is being used to configure the analyzer. The gas measurement will continue during this process.
SPAN CAL A[2]	Unit is performing SPAN calibration initiated automatically by the analyzer's AUTOCAL feature
SPAN CAL M[2]	Unit is performing SPAN calibration initiated manually by the user.
SPAN CAL R[2]	Unit is performing SPAN calibration initiated remotely through the COM ports or digital control inputs.
ZERO CAL A[2]	Unit is performing ZERO calibration procedure initiated automatically by the AUTOCAL feature
ZERO CAL M[2]	Unit is performing ZERO calibration procedure initiated manually by the user.
ZERO CAL R[2]	Unit is performing ZERO calibration procedure initiated remotely through the COM ports or digital control inputs.

[1] Other calibration procedures under **CAL** mode are described separately in Section 9.
[2] Only Appears on units with Z/S valve or IZS options..

4.1. SAMPLE MODE

This is the analyzer's standard operating mode. In this mode, the instrument is analyzing SO_2 and calculating concentrations.

4.1.1. TEST FUNCTIONS

A series of test functions is available at the front panel while the analyzer is in **SAMPLE** mode. These parameters provide information about the present operating status of the instrument and are useful during troubleshooting (refer to Section 12.1.2). They can also be recorded in one of the DAS channels (refer to Section 0) for data analysis. To view the test functions, press one of the **<TST TST>** buttons repeatedly in either direction.

Table 4-2: Test Functions Defined

DISPLAY	PARAMETER	UNITS	DESCRIPTION
RANGE	RANGE - - RANGE1 RANGE2	PPB, PPM, UGM & MGM	The Full Scale limit at which the reporting range of the analyzer's ANALOG OUTPUTS is currently set. THIS IS NOT the Physical Range of the instrument. Refer to Section 5.4 for more information. If DUAL or AUTO Range modes have been selected, two RANGE functions will appear, one for each range.
STABIL	STABILITY	mV	Standard deviation of SO_2 Concentration readings. Data points are recorded every ten seconds. The calculation uses the last 25 data points.
PRES	SAMPLE PRESSURE	in-Hg-A	The current pressure of the sample gas as it enters the sample chamber, measured between the SO_2 and Auto-Zero valves.
SAMP FL	SAMPLE FLOW	cm³/min (cc/m)	The flow rate of the sample gas through the sample chamber. This value is not measured but calculated from the sample pressure.
PMT	PMT Signal	mV	The raw output voltage of the PMT.
NORM PMT	NORMALIZED PMT Signal	mV	The output voltage of the PMT after normalization for offset and temperature/pressure compensation (if activated).
UV LAMP	Source UV Lamp Intensity	mV	The output voltage of the UV reference detector.
LAMP RATIO	UV Source lamp ratio	%	The current output of the UV reference detector divided by the reading stored in the CPU's memory from the last time a UV Lamp calibration was performed.
STR. LGT	Stray Light	ppb	The offset due to stray light recorded by the CPU during the last zero-point calibration performed.
DRK PMT	Dark PMT	mV	The PMT output reading recorded the last time the UV source lamp shutter was closed.
DRK LMP	Dark UV Source Lamp	mV	The UV reference detector output reading recorded the last time the UV source lamp shutter was closed.
SLOPE	SO_2 measurement Slope	-	The sensitivity of the instrument as calculated during the last calibration activity. The slope parameter is used to set the span calibration point of the analyzer.
OFFSET	SO_2 measurement Offset	mV	The overall offset of the instrument as calculated during the last calibration activity. The offset parameter is used to set the zero point of the analyzer response.
HVPS	HVPS	V	The PMT high voltage power supply.
RCELL TEMP	SAMPLE CHAMBER TEMP	°C	The current temperature of the sample chamber.
BOX TEMP	BOX TEMPERATURE	°C	The ambient temperature of the inside of the analyzer case.
PMT TEMP	PMT TEMPERATURE	°C	The current temperature of the PMT.
IZS TEMP[1]	IZS TEMPERATURE[1]	°C	The current temperature of the internal zero/span option. Only appears when IZS option is enabled.
TEST[2]	TEST SIGNAL[2]	mV	Signal of a user-defined test function on output channel A4.
TIME	CLOCK TIME	hh:mm:ss	The current day time for DAS records and calibration events.

[1] Only appears if Internal Gas Span Generator option is installed.

[2] Only appears if analog output A3 is actively reporting a test function.

To view the TEST Functions press the following button sequence:

```
┌───────────────────────────────────────────────────┐
│ SAMPLE          RANGE=500.00 PPB    SO2=XXXX        │
│                                                     │
│ <TST   TST>   CAL                        SETUP      │
└───────────────────────────────────────────────────┘
```

Toggle **<TST TST>** buttons to scroll through list of functions

- RANGE
- STABIL
- RSP
- PRES
- SAMP FL
- PMT
- NORM PMT
- UV LAMP
- LAMP RATIO
- STR LGTB
- DRK PMT
- DRK LMP
- SLOPE
- OFFSET
- HVPS
- RCELL ON
- RCELL TEMP
- BOX TEMP
- PMT TEMP
- IZS TEMP[1]
- PHT DRIVE
- TEST[2]
- TIME

[1] Only appears if the IZS option is installed.
[2] Only appears if analog output **A4** is actively reporting a **TEST FUNCTION**
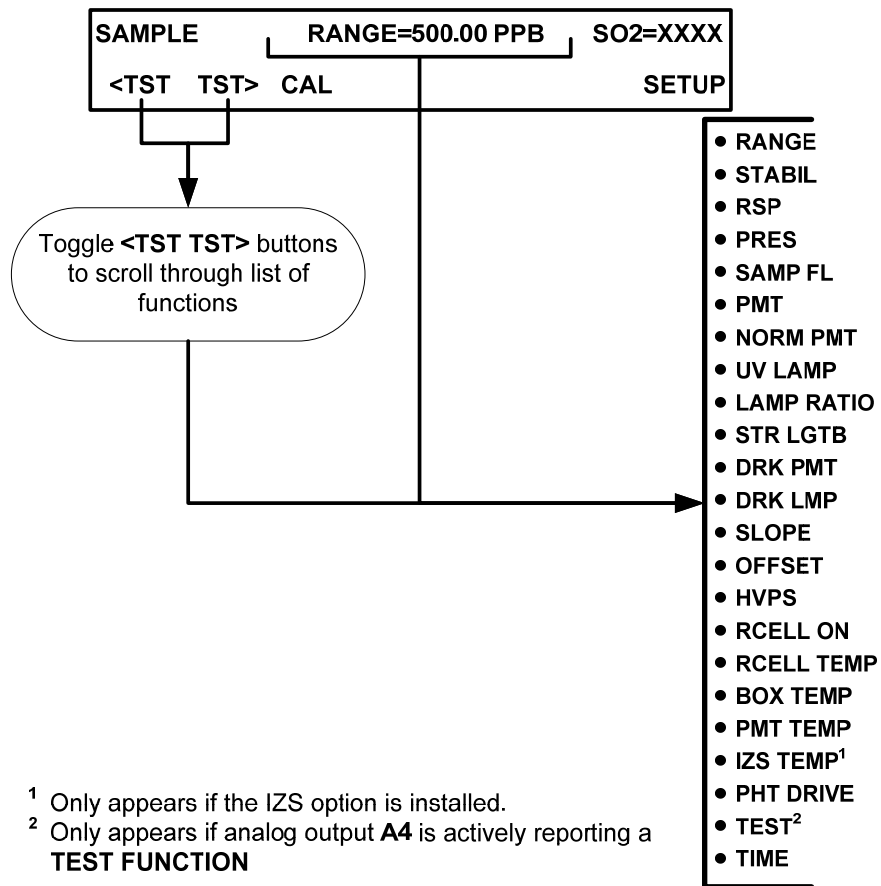
Figure 4-2: Viewing T100 TEST Functions

IMPORTANT

IMPACT ON READINGS OR DATA

A value of "XXXX" displayed for any of the TEST functions indicates an out-of-range reading or the analyzer's inability to calculate it. All pressure measurements are represented in terms of absolute pressure. Absolute, atmospheric pressure is 29.92 in-Hg-A at sea level. It decreases about 1 in-Hg per 300 m gain in altitude. A variety of factors such as air conditioning and passing storms can cause changes in the absolute atmospheric pressure.

4.1.2. WARNING MESSAGES

The most common instrument failures will be reported as a warning on the analyzer's front panel and through the COMM ports. Section 12.1.1 explains how to use these messages to troubleshoot problems. Section 12.1.3 shows how to view and clear warning messages. Table 4-3 lists all warning messages for the current version of software.

Table 4-3: List of Warning Messages

MESSAGE	MEANING
ANALOG CAL WARNING	The instrument's A/D circuitry or one of its analog outputs is not calibrated.
BOX TEMP WARNING	The temperature inside the T100 chassis is outside the specified limits.
CANNOT DYN SPAN	Remote span calibration failed while the dynamic span feature was set to turned on
CANNOT DYN ZERO	Remote zero calibration failed while the dynamic zero feature was set to turned on
CONFIG INITIALIZED	Configuration was reset to factory defaults or was erased.
DARK CAL WARNING	Dark offset above limit specified indicating that too much stray light is present in the sample chamber.
DATA INITIALIZED	DAS data storage was erased.
HVPS WARNING	High voltage power supply for the PMT is outside of specified limits.
IZS TEMP WARNING	On units with IZS options installed: The permeation tube temperature is outside of specified limits.
PMT DET WARNING	PMT detector output outside of operational limits.
PMT TEMP WARNING	PMT temperature is outside of specified limits.
RCELL TEMP WARNING	Sample chamber temperature is outside of specified limits.
REAR BOARD NOT DET	The CPU is unable to communicate with the motherboard.
RELAY BOARD WARN	The firmware is unable to communicate with the relay board.
SAMPLE FLOW WARN	The flow rate of the sample gas is outside the specified limits.
SAMPLE PRESS WARN	Sample pressure outside of operational parameters.
SYSTEM RESET	The computer was rebooted.
UV LAMP WARNING	The UV lamp intensity measured by the reference detector reading too low or too high

To view and clear warning messages, press:
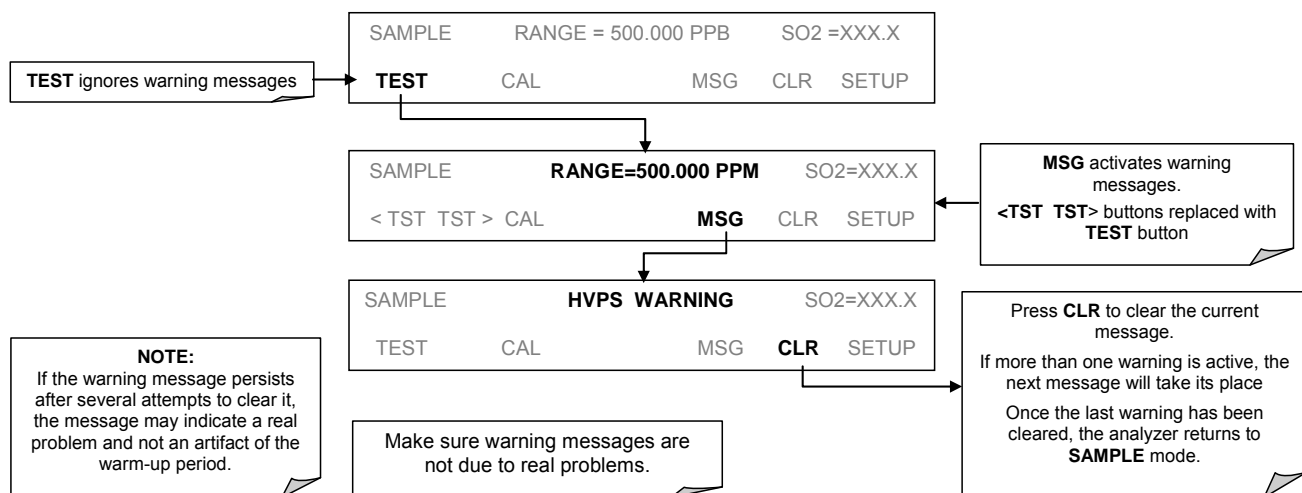
Figure 4-3: Viewing and Clearing T100 WARNING Messages

4.2. CALIBRATION MODE

Pressing the **CAL** button switches the analyzer into calibration mode. In this mode, the user can calibrate the instrument with the use of calibrated zero or span gases.

If the instrument includes either the zero/span valve option or IZS option, the display will also include **CALZ** and **CALS** buttons. Pressing either of these buttons also puts the instrument into multipoint calibration mode.

- The **CALZ** button is used to initiate a calibration of the zero point.

- The **CALS** button is used to calibrate the span point of the analyzer. It is recommended that this span calibration is performed at 80% of full scale of the analyzer's currently selected reporting range.

Because of their critical importance and complexity, calibration operations are described in detail in other sections of the manual:

- Section 9 details basic calibration and calibration check operations.

- Section 10 describes how to perform an EPA protocol calibration.

IMPORTANT

IMPACT ON READINGS OR DATA

To avoid inadvertent adjustments to critical settings, activate calibration security by enabling password protection in the SETUP – PASS menu (5.5).

4.3. SETUP MODE

The **SETUP** mode contains a variety of choices that are used to configure the analyzer's hardware and software features, perform diagnostic procedures, gather information on the instrument's performance and configure or access data from the internal data acquisition system (DAS). For a visual representation of the software menu trees, refer to Appendix A-1. Setup Mode is divided between Primary and Secondary Setup menus and can be protected through password security.

4.3.1. PASSWORD SECURITY

Setup Mode can be protected by password security through the SETUP>PASS menu (Section 5.5) to prevent unauthorized or inadvertent configuration adjustments.

4.3.2. PRIMARY SETUP MENU

Table 4-4: Primary Setup Mode Features and Functions

MODE OR FEATURE	CONTROL BUTTON	DESCRIPTION	MANUAL SECTION
Analyzer Configuration	**CFG**	Lists key hardware and software configuration information.	5.1
Auto Cal Feature	**ACAL**	Used to set up and operate the AutoCal feature. Only appears if the analyzer has one of the internal valve options installed.	5.2 & 9.8
Internal Data Acquisition (DAS)	**DAS**	Used to set up the DAS system and view recorded data.	5.3 & 0
Analog Output Reporting Range Configuration	**RNGE**	Used to configure the output signals generated by the instrument's Analog outputs.	5.4
Calibration Password Security	**PASS**	Turns the calibration password protection feature ON/OFF.	5.5
Internal Clock Configuration	**CLK**	Used to Set or adjust the instrument's internal clock.	5.6
Advanced **SETUP** features	**MORE**	This button accesses the instruments secondary setup menu.	See Table 4-5

4.3.3. SECONDARY SETUP MENU (SETUP>MORE)

Table 4-5: Secondary Setup Mode Features and Functions

MODE OR FEATURE	MENU ITEM	DESCRIPTION	MANUAL SECTION
External Communication Channel Configuration	**COMM**	Used to set up and operate the analyzer's various external I/O channels including RS-232; RS 485, modem communication and/or Ethernet access.	5.7 & 6
System Status Variables	**VARS**	Used to view various variables related to the instrument's current operational status	5.8
System Diagnostic Features	**DIAG**	Used to access a variety of functions that are used to configure, test or diagnose problems with a variety of the analyzer's basic systems	5.9

IMPORTANT

IMPACT ON READINGS OR DATA

Any changes made to a variable during the SETUP procedures are not acknowledged by the instrument until the ENTR button is pressed. If the EXIT button is pressed before the ENTR button, the analyzer will beep, alerting the user that the newly entered value has not been accepted.

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5. SETUP MENU

The SETUP menu is used to set instrument parameters for performing configuration, calibration, reporting and diagnostics operations according to user needs.

5.1. SETUP – CFG: CONFIGURATION INFORMATION

Pressing the CFG button displays the instrument configuration information. This display lists the analyzer model, serial number, firmware revision, software library revision, CPU type and other information. Use this information to identify the software and hardware when contacting Technical Support. Special instrument or software features or installed options may also be listed here.
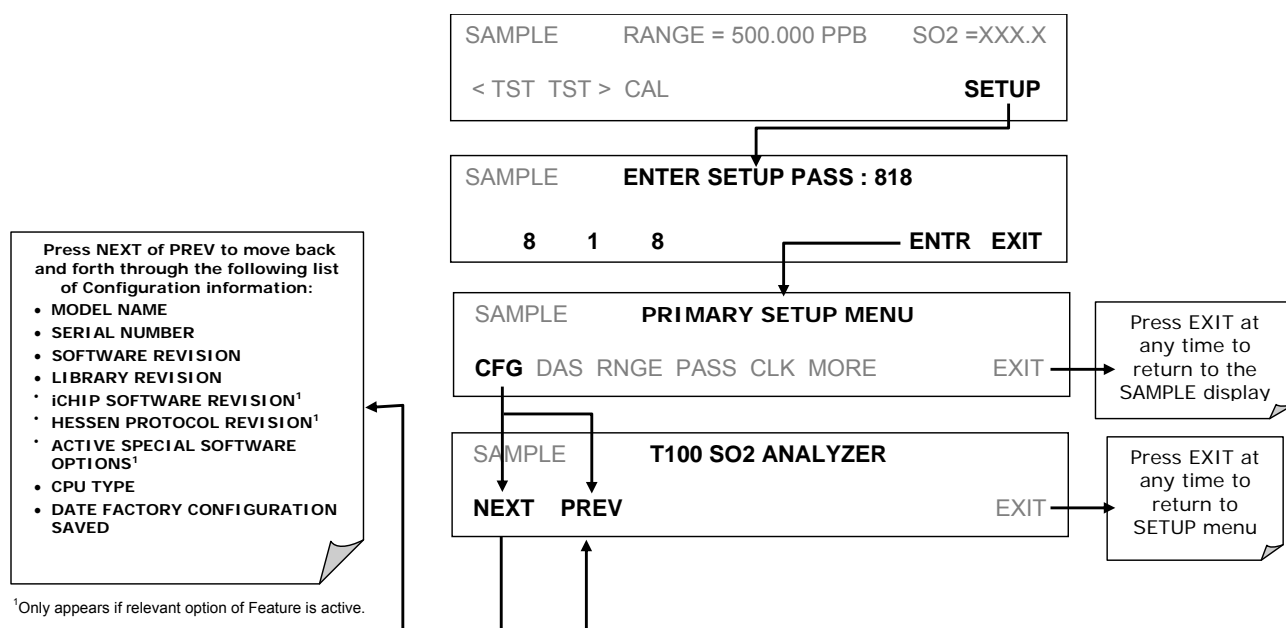
Figure 5-1: SETUP – Configuration Information

5.2. SETUP – ACAL: AUTOMATIC CALIBRATION OPTION

The menu button for this option appears only when the instrument has the zero span and/or IZS options. See Section 9.8 for details.

5.3. SETUP – DAS: INTERNAL DATA ACQUISITION SYSTEM

Use the SETUP>DAS menu to capture and record data. Refer to Section 0 for configuration and operation details.

5.4. SETUP – RNGE: ANALOG OUTPUT REPORTING RANGE CONFIGURATION

Use the SETUP>RNGE menu to configure output reporting ranges, including scaled reporting ranges to handle data resolution challenges. This section describes configuration for Single, Dual, and Auto Range modes.

5.4.1. AVAILABLE ANALOG OUTPUT SIGNALS

The analyzer has three active analog output signals, accessible through a connector on the rear panel.
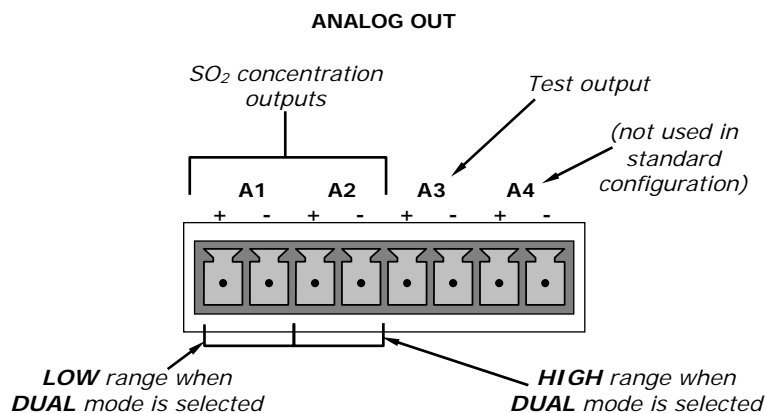
Figure 5-2: SETUP – Analog Output Connector

All three outputs can be configured either at the factory or by the user for full scale outputs of 0.1 VDC, 1VDC, 5VDC or 10VDC. Additionally **A1** and **A2** may be equipped with optional 0-20 mA DC current loop drivers and configured for any current output within that range (e.g. 0-20, 2-20, 4-20, etc.). The user may also adjust the signal level and scaling of the actual output voltage or current to match the input requirements of the recorder or data logger (Refer to Section 6.9.4.3 and 6.9.4.5).

In its basic configuration, the **A1** and **A2** channels of the T100 output a signal that is proportional to the SO_2 concentration of the sample gas. Several operating modes are available which allow:

- Single range mode (**SNGL** Mode, refer to Section 6.7.4): Both outputs are slaved together and will represent the same concentration span (e.g. 0-50 ppm); however their electronic signal levels may be configured for different ranges (e.g. 0-10 VDC vs. 0-.1 VDC – Refer to Section 6.9.4).

- Dual range mode(**DUAL** mode, refer to Section 6.7.5): The two outputs can to configured for separate and independent units of measure and measurement spans as well as separate electronic signal levels.

- Auto range mode (**AUTO** mode, refer to Section 6.7.6) gives the analyzer the ability to automatically switch the A1 and A2 analog outputs between two ranges (low and high) dynamically as the concentration value fluctuates.

EXAMPLE:
A1 OUTPUT: Output Signal = 0-5 VDC representing 0-1000 ppm concentration values
A2 OUTPUT: Output Signal = 0 – 10 VDC representing 0-500 ppm concentration values.
A3 OUTPUT: Test channel; e.g., PMT signal = 0-5V
Output **A4** is not available on the T100 Analyzer in standard configuration.

5.4.2. PHYSICAL RANGE VERSUS ANALOG OUTPUT REPORTING RANGES

The entire measurement range of the T100 is 0 – 20,000 ppb, but many applications use only a small part of the analyzer's full measurement range. This creates two performance challenges:

The width of the T100's physical range can create data resolution problems for most analog recording devices. For example, in an application where the expected concentration of SO_2 is typically less than 500 ppb, the full scale of expected values is only 0.25% of the instrument's full 20,000 ppb measurement range. Unmodified, the corresponding output signal would also be recorded across only 0.25% of the range of the recording device.

The T100 solves this problem by allowing the user to select a scaled reporting range for the analog outputs that only includes that portion of the physical range relevant to the specific application. Only the reporting range of the analog outputs is scaled, the physical range of the analyzer and the readings displayed on the front panel remain unaltered.

Applications where low concentrations of SO_2 are measured require greater sensitivity and resolution than typically necessary for measurements of higher concentrations.

The T100 solves this issue by using two hardware physical ranges that cover the instrument's entire 0 and 20,000 ppb measurement range: a 0 to 2,000 ppb physical range for increased sensitivity and resolution when measuring very low SO_2 concentrations, and a 0 to 20,000 ppb physical range for measuring higher SO_2 concentrations. The analyzer's software automatically selects which physical range is in effect based on the analog output reporting range selected by the user.

- If the high end of the selected reporting range is $\le$ 2,000 ppb. The low physical range is selected.

- If the high end of the selected reporting range is $\ge$ 2,001 ppb. The high physical range is selected.

Once properly calibrated, the analyzer's front panel display will accurately report concentrations along the entire span of its 0 and 20,000 ppb physical range regardless of which reporting range has been selected for the analog outputs and which physical range is being used by the instrument's software.

5.4.3. REPORTING RANGE MODES: SINGLE, DUAL, AUTO RANGES

The T100 provides three analog output range modes to choose from:

- Single range (**SNGL**) mode sets a single maximum range for the analog output. If single range is selected (refer to Section 5.4.3.1) both outputs are slaved together and will represent the same measurement span (e.g. 0-50 ppm), however their electronic signal levels may be configured for different ranges (e.g. 0-10 VDC vs. 0-.1 VDC – Refer to Section 5.9.3.1).

- Dual range (**DUAL**) allows the A1 and A2 outputs to be configured with different measurement spans (refer to Section 5.4.3.2).

- Auto range (**AUTO**) mode gives the analyzer to ability to output data via a low range and high range. When this mode is selected (refer to Section 5.4.3.3) the T100 will automatically switch between the two ranges dynamically as the concentration value fluctuates.

Also, in this mode the RANGE Test function displayed on the front panel during SAMPLE mode will be replaced by two separate functions, Range1 and Range2.

Range status is also output via the External Digital I/O Status Bits (refer to Section 8.1.1).

To select the Analog Output Range Type press:
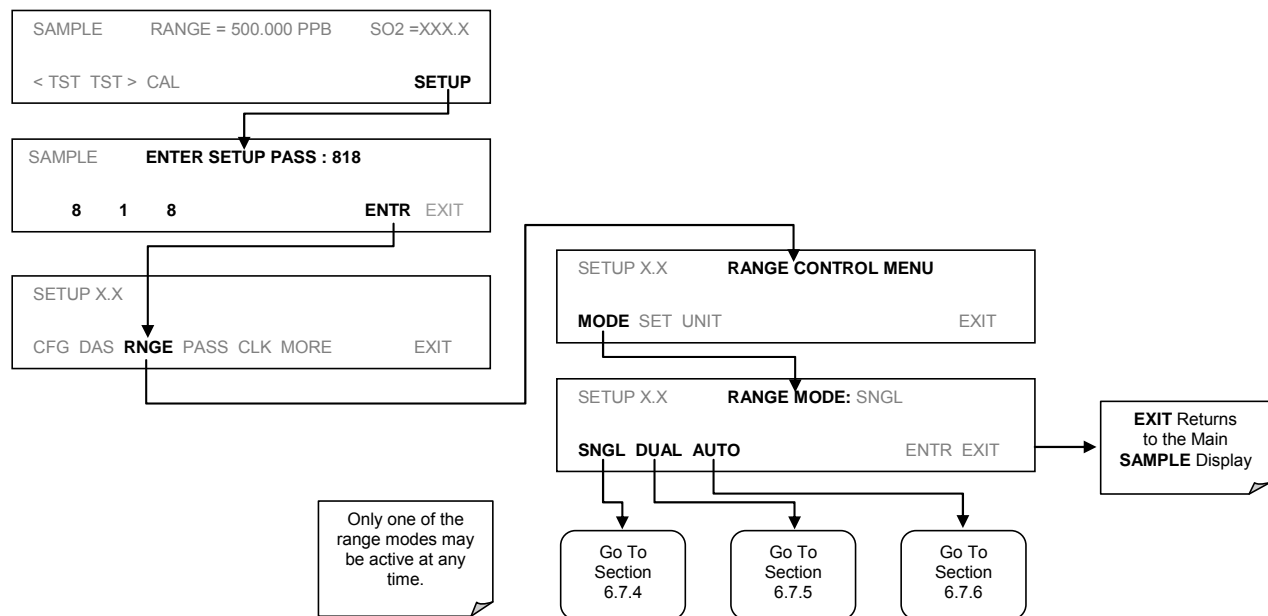
Figure 5-3: SETUP RNGE – Reporting Range Mode

5.4.3.1. **SINGLE RANGE MODE (SNGL)**

The default range mode for the analyzer is single range, in which all analog concentration outputs are set to the same reporting range. This reporting range can be set to any value between 0.1 ppb and 20,000 ppb.

While the two outputs always have the same reporting range, the span and scaling of their electronic signals may also be configured for different differently (e.g., **A1** = 0-10 V; **A2** = 0-0.1 V).

To select **SNGLE** range mode and to set the upper limit of the range, press:
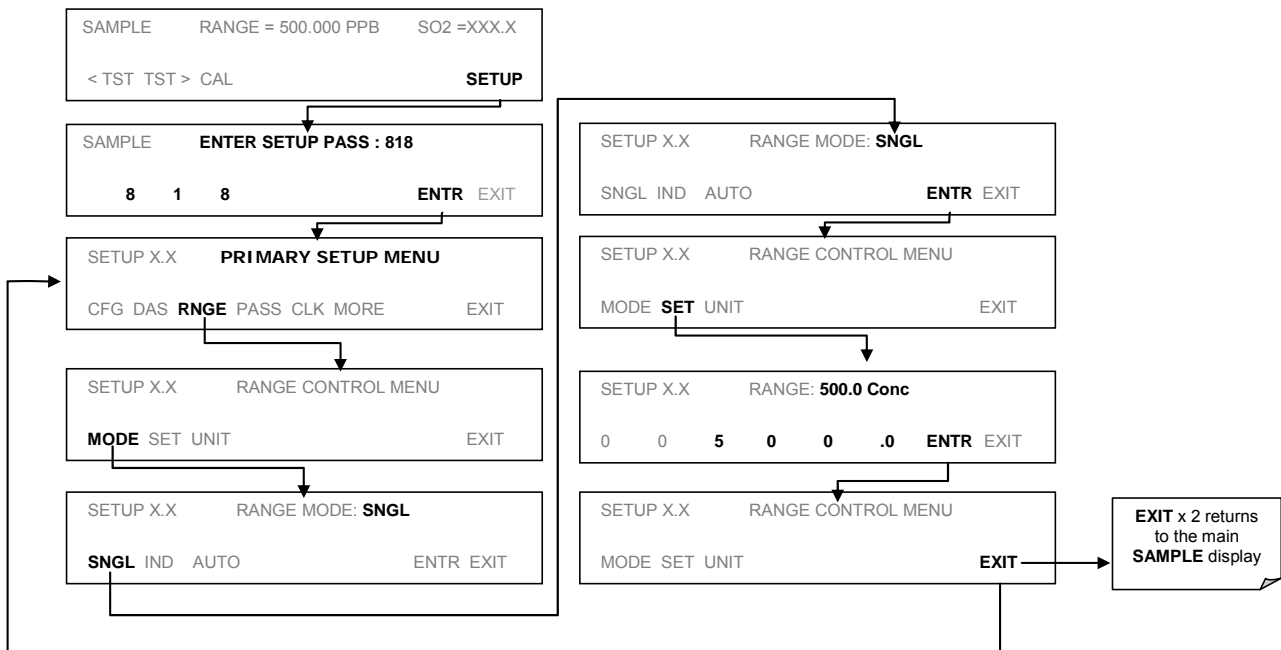
Figure 5-4: SETUP RNGE – Single Range Mode

5.4.3.2. **DUAL RANGE MODE (DUAL)**

Selecting Dual Range mode allows the **A1** and **A2** outputs to be configured with different reporting ranges. The analyzer software calls these two ranges low and high. The Low range setting corresponds with the analog output labeled **A1** on the rear panel of the instrument. The high range setting corresponds with the **A2** output. While the software names these two ranges low and high, they do not have to be configured that way. For example: the low range can be set for a span of 0-150 ppb while the high range is set for 0-50 ppb.

In **DUAL** range mode the **RANGE** test function displayed on the front panel will be replaced by two separate functions:

- range1: The range setting for the A1 output.

- range2: The range setting for the A2 output.

To set the ranges press following control button sequence
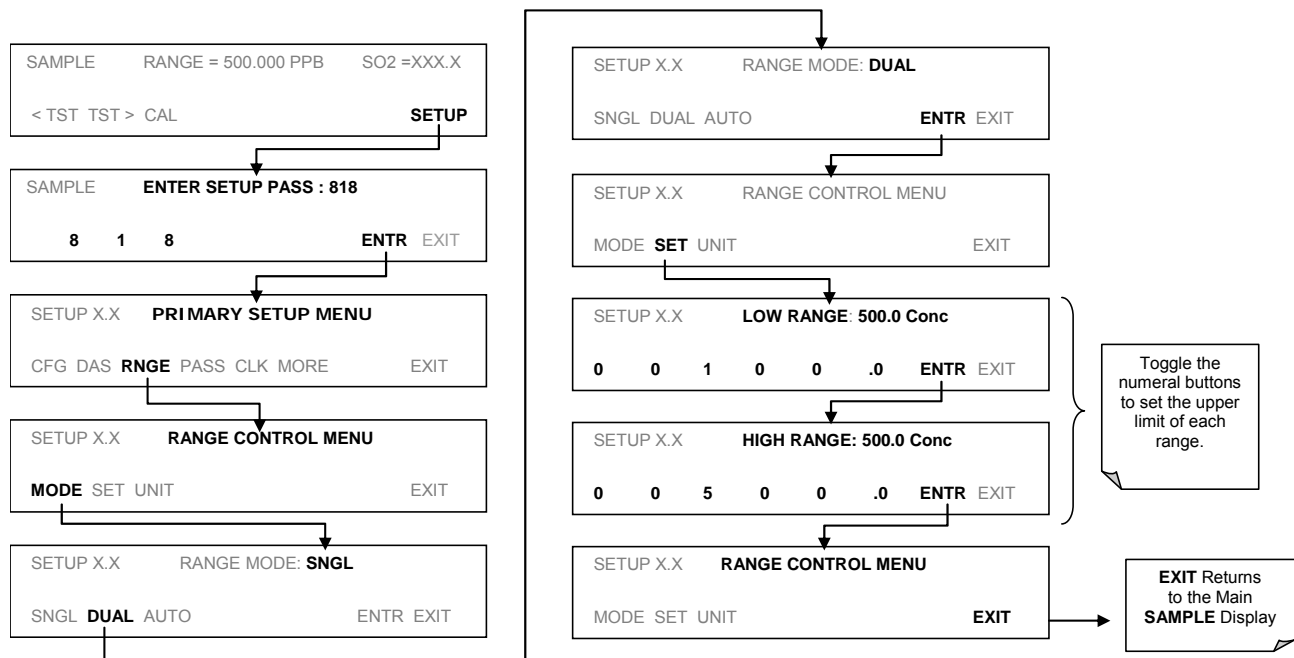
Figure 5-5: SETUP RNGE – Dual Range Mode

IMPORTANT	**IMPACT ON READINGS OR DATA**
	In DUAL range mode the LOW and HIGH ranges have separate slopes and offsets for computing SO$_2$ concentration. The two ranges must be independently calibrated.

5.4.3.3. **AUTO RANGE MODE (AUTO)**

In AUTO range mode, the analyzer automatically switches the reporting range between two user-defined ranges (low and high). The unit will switch from low range to high range when either the SO_2 concentration exceeds 98% of the low range span. The unit will return from high range back to low range once both the SO_2 concentration falls below 75% of the low range span.

In **AUTO** Range mode the instrument reports the same data in the same range on both the **A1** and **A2** outputs and automatically switches both outputs between ranges as described above. Also, the **RANGE** test function displayed on the front panel will be replaced by two separate functions:

- **RANGE1**: The **LOW** range setting for all analog outputs.

- **RANGE2**: The **HIGH** range setting for all analog outputs.

The high/low range status is also reported through the external, digital status bits (refer to Section 8.1.1).

To set individual ranges press the following control button sequence.
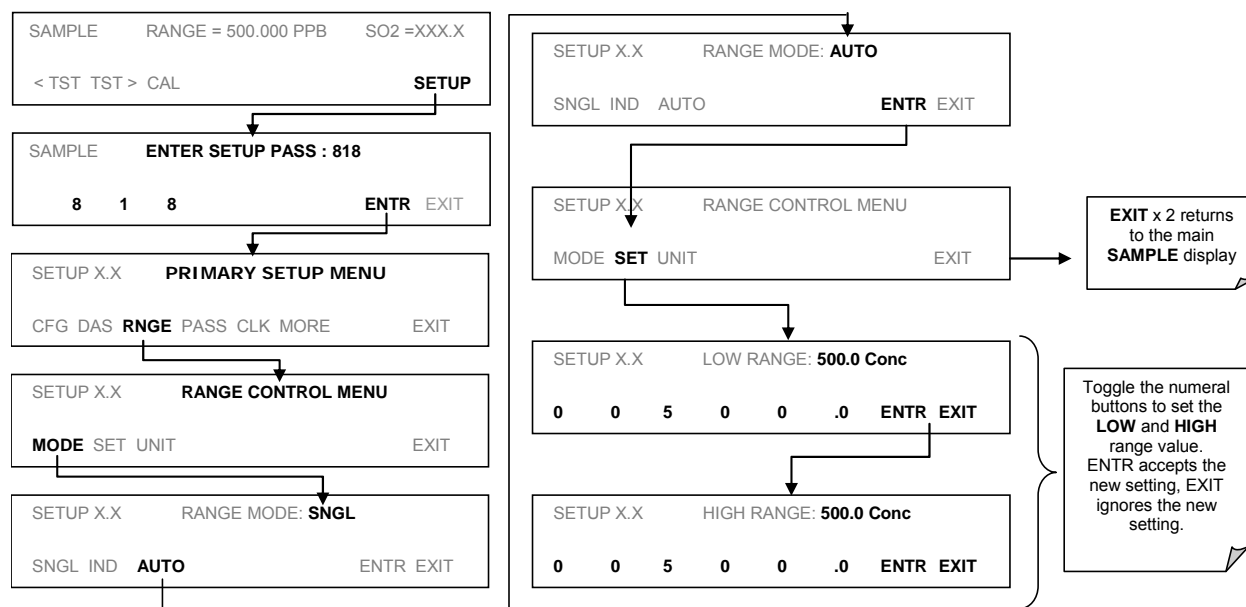
Figure 5-6: SETUP RNGE – Auto Range Mode

IMPORTANT   **IMPACT ON READINGS OR DATA**
In AUTO range mode, the LOW and HIGH ranges have separate slopes and offsets for computing SO$_2$ concentration. The two ranges must be independently calibrated.

5.4.4. RANGE UNITS

The T100 can display concentrations in parts per billion (10^9 mols per mol, PPB), parts per million (10^6 mols per mol, PPM), micrograms per cubic meter ($\mu g/m^3$, UGM) or milligrams per cubic meter (mg/m^3, MGM). Changing units affects all of the display, analog outputs, COM port and DAS values for all reporting ranges regardless of the analyzer's range mode.

To change the concentration units:
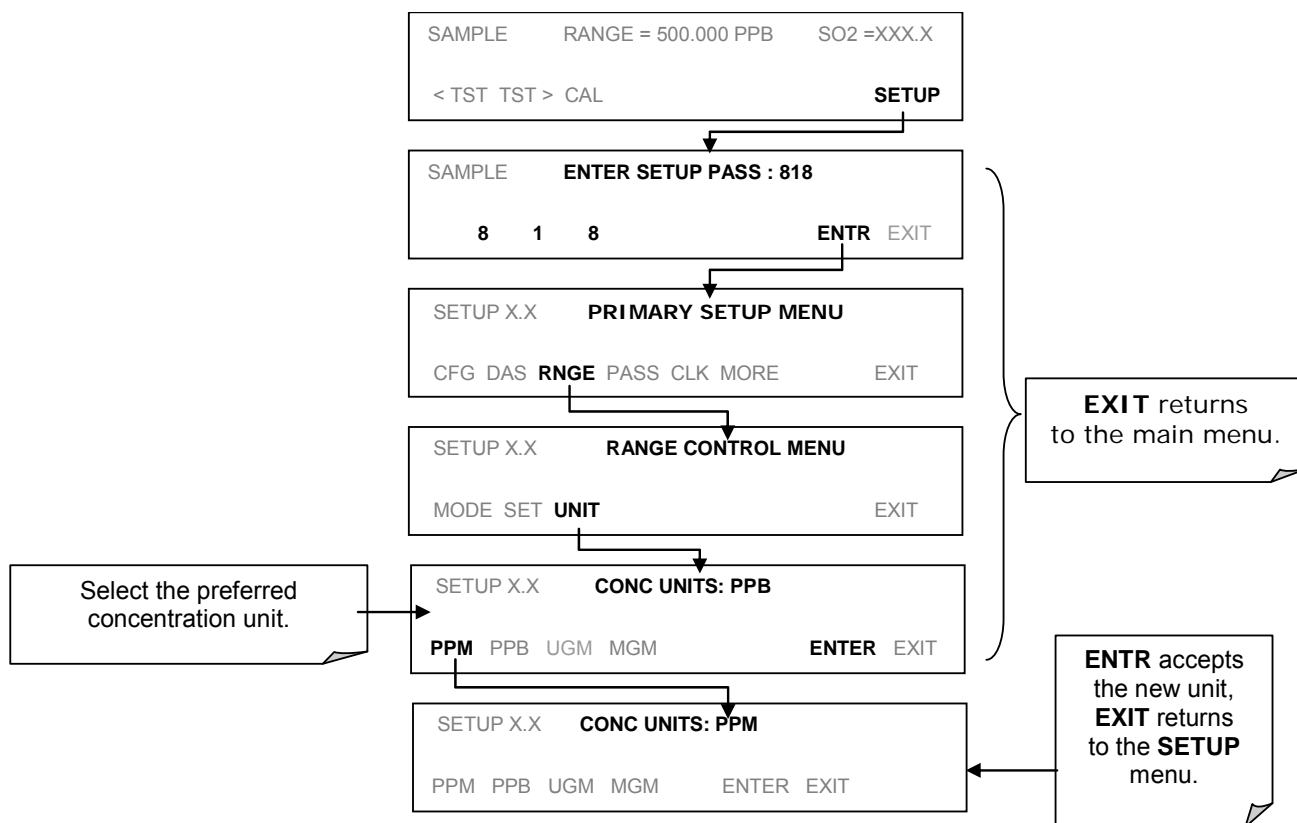
Figure 5-7: SETUP RNGE – Concentration Units Selection

IMPORTANT	**IMPACT ON READINGS OR DATA**
	Concentrations displayed in mg/m³ and µg/m³ use 0°C and 760 Torr as standard temperature and pressure (STP). Consult your local regulations for the STP used by your agency. See Section 5.4.4.1 for converting volumetric to mass units

5.4.4.1. **CONVERTING MICROGRAMS PER CUBIC METER TO PARTS PER MILLION**

The conversion between micrograms per cubic meter and parts per million is based on standard conditions (0^oC and 101.325 kPa) where one mole of an ideal gas occupies 22.414 L. Thus, converting the mass of the pollutant M_p in grams to its equivalent volume V_p in liters at standard temperature and pressure (STP) takes the following equation:

$$V_p = [(M_p)/(MW)] \times 22.414 \text{ L} \cdot \text{mol}^{-1}$$

Where MW is the molecular weight of the pollutant in units of grams per mole. For readings made at temperatures and pressures other than standard conditions, the standard volume, 22.414 L·mol^{-1}, must be corrected. The ideal gas law to make the correction can be used:

$$(22.414 \text{ L} \cdot \text{mol}^{-1}) \times [(T_2)/(273 \text{ K})] \times [(101.325 \text{ kPa})/(P_2)]$$

Where T_2 and P_2 are the absolute temperature (in Kelvin) and absolute pressure (in kilopascals) at which the readings were made. Because parts per million is a volume ratio, it can be written as:

$$ppm = (V_p)/(V_a + V_p)$$

where V_a is the volume of the air in cubic meters at the temperature and pressure at which the measurement was taken. Then combine equations to yield:

$$ppm = \frac{\{[(M_p)/(MW)] \times (22.414 \text{ L} \cdot \text{mol}^{-1}) \times [(T_2)/(273 \text{ K})] \times [(101.325 \text{ kPa})/(P_2)]\}}{(V_a) \times (1000 \text{ L} \cdot \text{m}^{-3})}$$

where M_p is the mass of the pollutant of interest in micrograms. The factors converting micrograms to grams and liters to millions of liters cancel one another. Unless otherwise stated, it is assumed that $V_a = 1.00 \text{ m}^3$

Example:

A 1-m^3 sample of air was found to contain 80 μg·m^{-3} of SO_2. The temperature and pressure were 25.0 ^{o}C and 103.193 kPa when the air sample was taken. What was the SO_2 concentration in parts per million?

Solution:

First, determine the MW of SO_2:

$$MW \text{ of } SO_2 = 32.06 + 2(15.9994) = 64.06 \text{ g} \cdot \text{mol}^{-1}$$

Next, convert the temperature from Celsius to Kelvin:

$$25^o\text{C} + 273 \text{ K} = 298 \text{ K}$$

Using the equation derived above, Concentration is:

$$\{[(80 \text{ μg})/(64.06 \text{ g} \cdot \text{mol}^{-1})] \times (22.414 \text{ L} \cdot \text{mol}^{-1}) \times [(298 \text{ K})/(273 \text{ K})] \times [(101.325 \text{ kPa})/(103.193 \text{ kPa})]\} / [(1 \text{ m}^3) \times (1000 \text{ L} \cdot \text{m}^3)]$$

$$= 0.030 \text{ ppm of } SO_2$$

5.4.5. DILUTION RATIO (OPTION)

The dilution ratio is a software option that allows the user to compensate for any dilution of the sample gas before it enters the sample inlet. Once the degree of dilution is known, add an appropriate scaling factor to the analyzer's SO2 concentration calculation so that the measurement range and concentration values reflect the undiluted values when shown on the instrument's front panel display screen and reported via the analog and serial outputs.

Using the dilution ratio option is a 4-step process:

1. Select reporting range units: Follow the procedure in Section 5.4.4

2. Select the range: Use the procedures in Section 5.4. Ensure that the SPAN value entered is the maximum expected concentration of the undiluted calibration gas and that the span gas is either supplied through the same dilution inlet system as the sample gas or has an appropriately lower actual concentration. For example, with a dilution set to 100, a 1 ppm gas can be used to calibrate a 100 ppm sample gas if the span gas is not routed through the dilution system. On the other hand, if a 100 ppm span gas is used, it needs to pass through the same dilution steps as the sample gas.

3. Set the dilution factor as a gain (e.g., a value of 20 means 20 parts diluent and 1 part of sample gas):
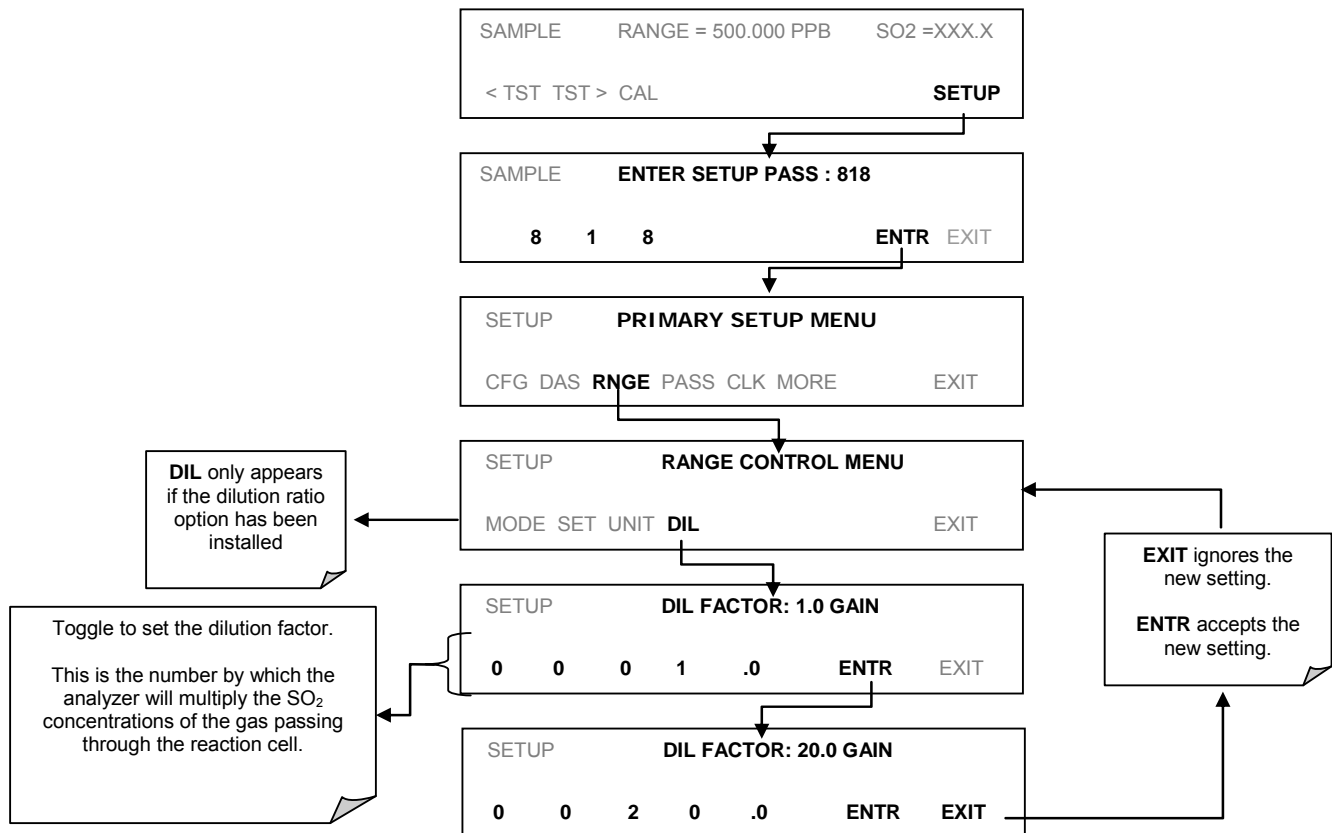
Figure 5-8: SETUP RNGE – Dilution Ratio

The analyzer multiplies the measured gas concentrations with this dilution factor and displays the result.

_ _

IMPORTANT   **IMPACT ON READINGS OR DATA**

Once the above settings have been entered, the instrument needs to be recalibrated using one of the methods discussed in Section 9.

_ _

5.5. SETUP – PASS: PASSWORD PROTECTION

The menu system provides password protection of the calibration and setup functions to prevent unauthorized adjustments. When the passwords have been enabled in the **PASS** menu item, the system will prompt the user for a password anytime a password-protected function (e.g., SETUP) is selected. This allows normal operation of the instrument, but requires the password (101) to access to the menus under SETUP. When PASSWORD is disabled (SETUP>OFF), any operator can enter the Primary Setup (SETUP) and Secondary Setup (SETUP>MORE) menus. Whether PASSWORD is enabled or disabled, a password (default 818) is required to enter the VARS or DIAG menus in the SETUP>MORE menu.

Table 5-1: Password Levels

PASSWORD	LEVEL	MENU ACCESS ALLOWED
Null (000)	Operation	All functions of the main menu (top level, or Primary, menu)
101	Configuration/Maintenance	Access to Primary and Secondary SETUP Menus when PASSWORD is enabled
818	Configuration/Maintenance	Access to Secondary SETUP Submenus **VARS** and **DIAG** whether PASSWORD is enabled or disabled.

To enable or disable passwords, press:
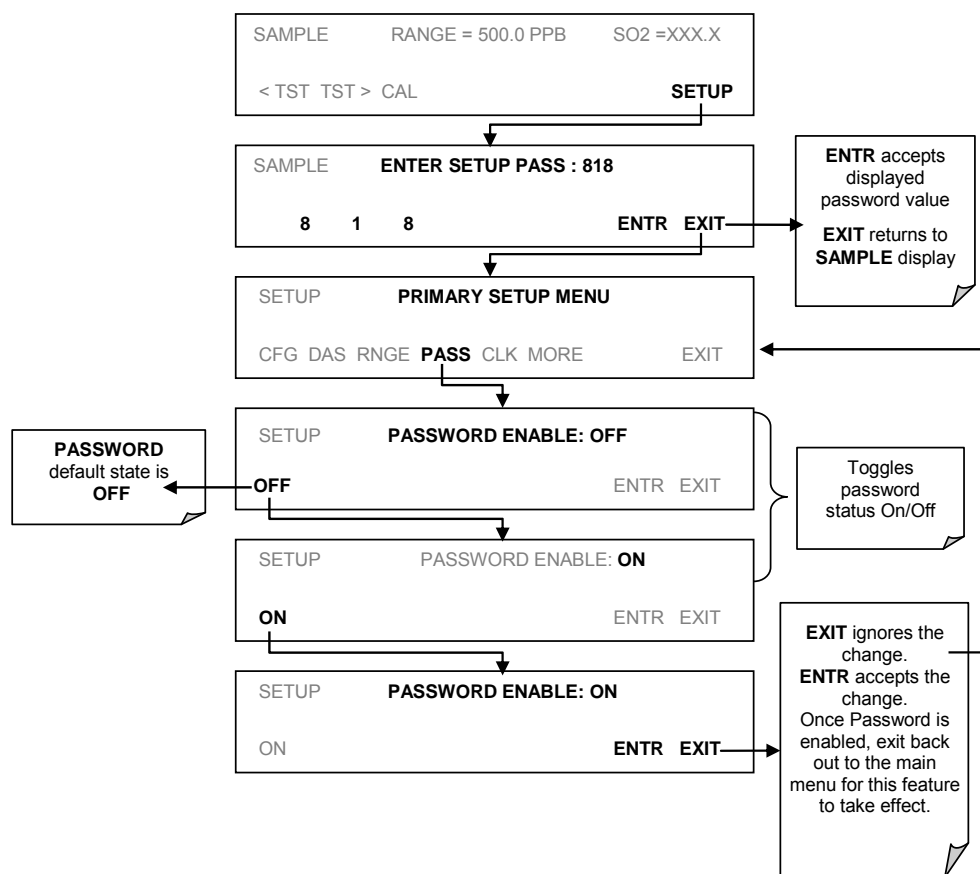
Figure 5-9: SETUP – Enable Password Security

If the password feature is enabled, then when entering either Calibration or Setup Mode, the default password displayed will be 000, and the new password must be input. Example follows for Calibration Mode:
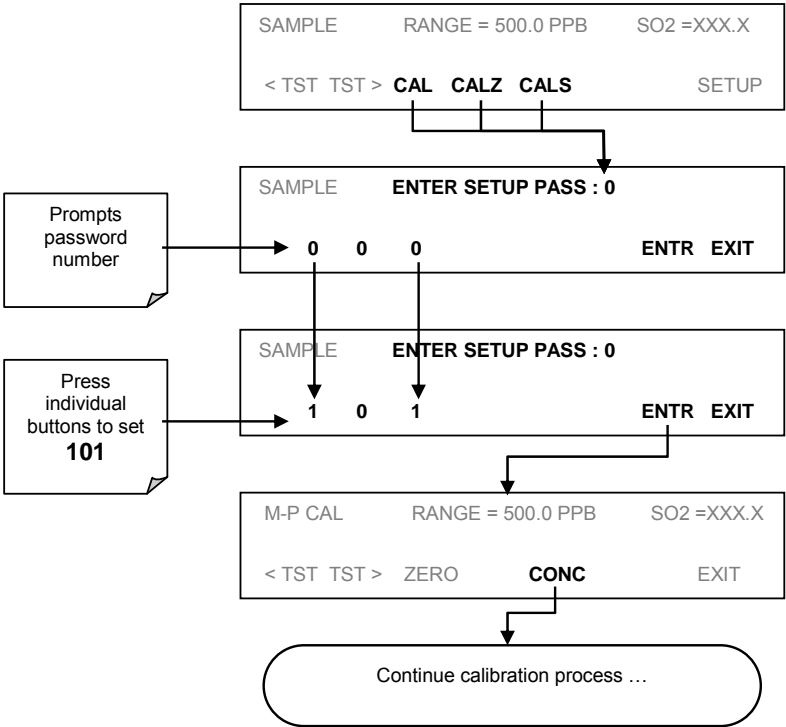
Figure 5-10:   SETUP – Enter Calibration Mode Using Password

5.6. SETUP – CLK: SETTING THE INTERNAL TIME-OF-DAY CLOCK

The T100 has a built-in clock for the AutoCal timer, Time **TEST** functions, and time stamps on COM port messages and DAS data entries. To set the time-of-day, press:
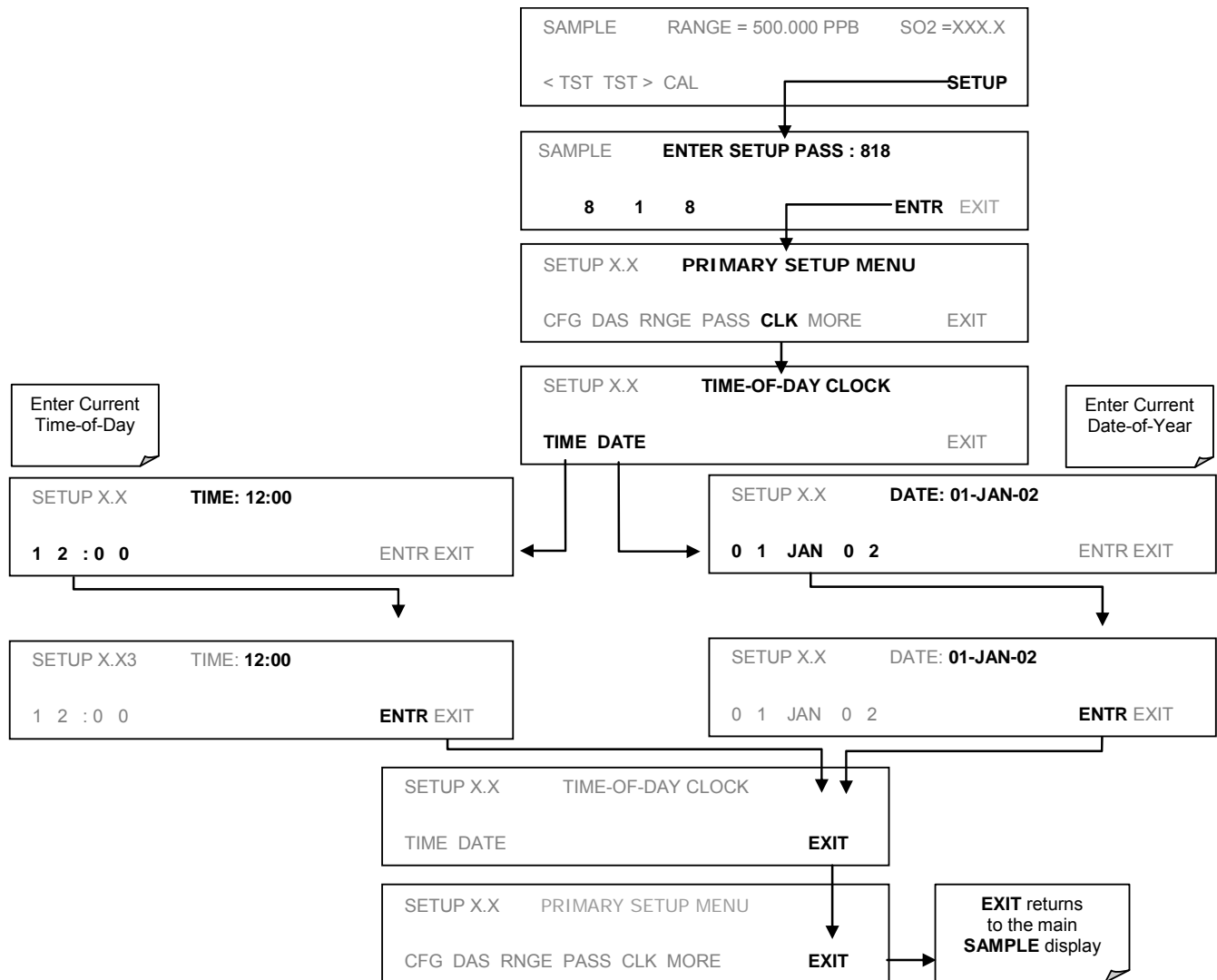
Figure 5-11:   **SETUP – Clock**

In order to compensate for CPU clocks, which may run fast or slow, there is a variable to speed up or slow down the clock by a fixed amount every day. To change this variable, press:
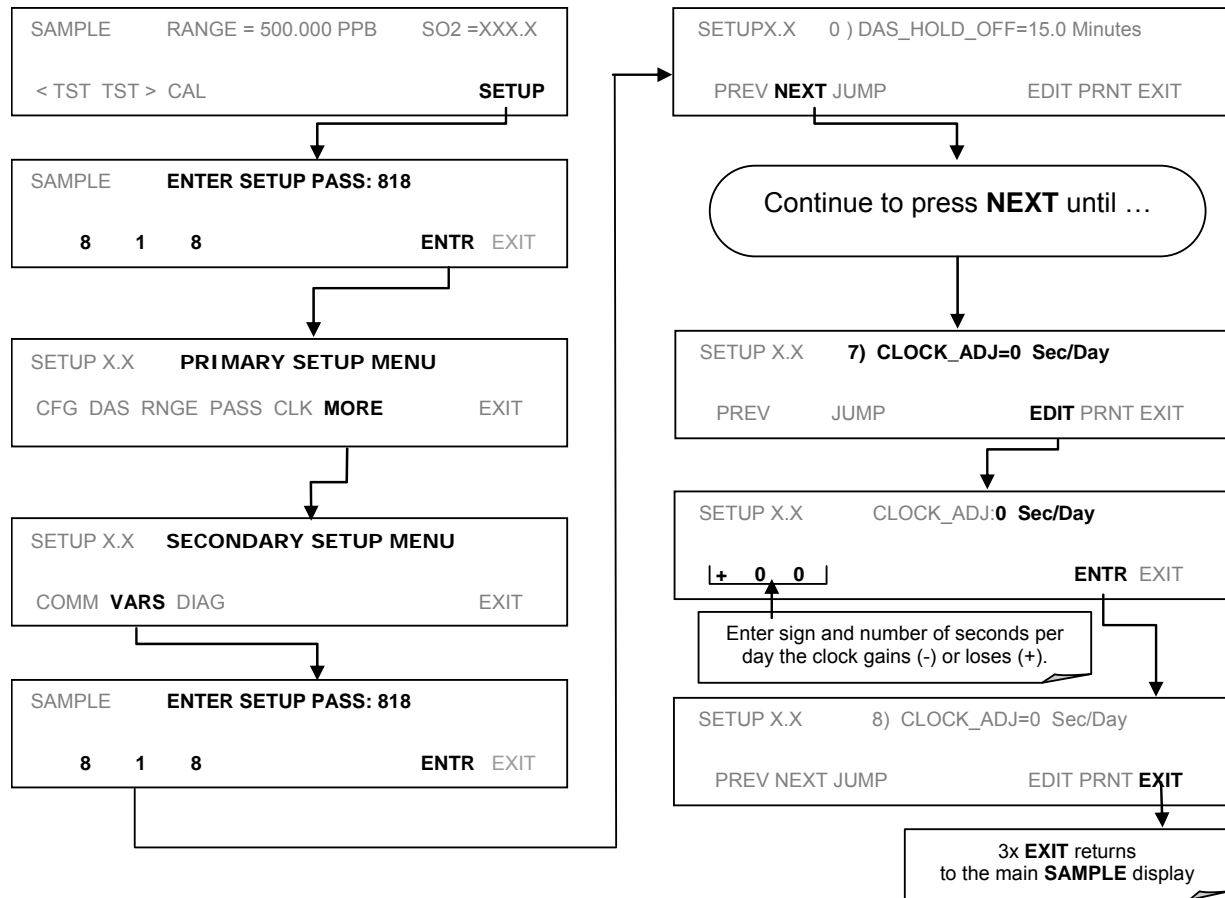
Figure 5-12:   **SETUP – Clock Speed Variable**

5.7. SETUP – COMM: COMMUNICATIONS PORTS

This section introduces the communications setup menu; Section 6 provides the setup instructions and operation information. Press SETUP>ENTR>MORE>COMM to arrive at the communications menu.

```
 SAMPLE       RANGE = 500.000 PPB      SO2 =XXX.X

 < TST  TST > CAL                              SETUP
```

If the default password 818 is replaced by 000, then Password Protection has been enabled. Refer to **SETUP: PASS**.

```
 SAMPLE          ENTER SETUP PASS : 818

      8     1     8                     ENTR   EXIT
```

```
 SETUP X.X      PRIMARY SETUP MENU

 CFG  DAS  RNGE  PASS  CLK  MORE            EXIT
```

```
 SETUP X.X      SECONDARY SETUP MENU

 COMM   VARS   DIAG                         EXIT
```

```
 SETUP X.X      COMMUNICATIONS MENU

 ID    INET    COM1  COM2                   EXIT
```
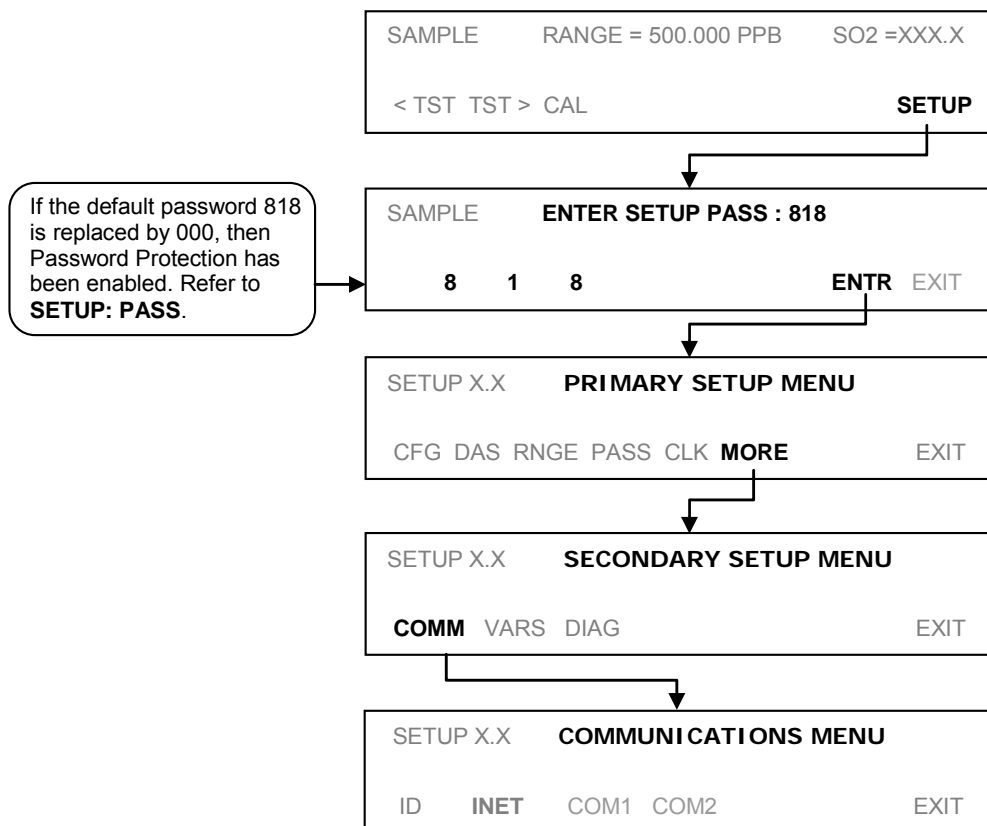
Figure 5-13:   SETUP – COMM Menu

5.7.1. ID (INSTRUMENT IDENTIFICATION)

Press ID to display and/or change the Machine ID, which must be changed to a unique identifier (number) when more than one instrument of the same model is used in a multidrop configuration (0) or when applying MODBUS protocol (Section 6.6.1). The default ID is the same as the model number; for the Model T100, the ID is 0100. Press any button(s) in the MACHINE ID menu (Figure 5-14) until the Machine ID Parameter field displays the desired identifier.
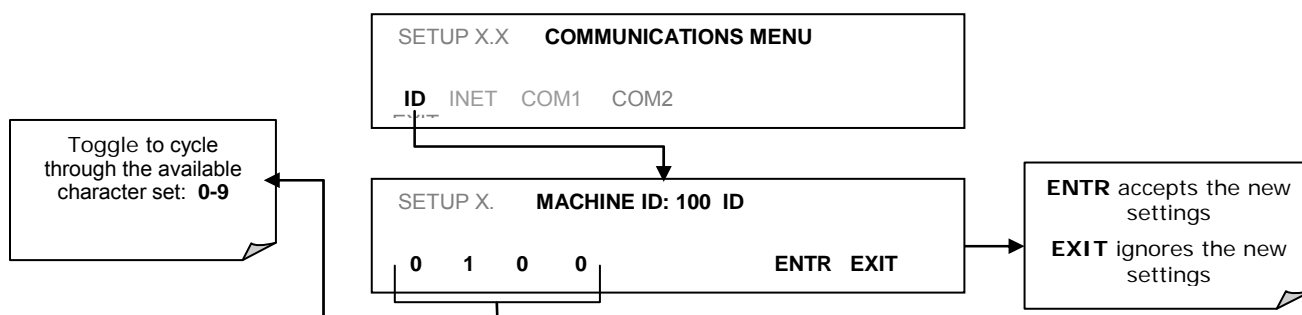
Figure 5-14:   COMM – Machine ID

The ID can be any 4-digit number and can also be used to identify analyzers in any number of ways (e.g. location numbers, company asset number, etc.)

5.7.2. INET (ETHERNET)

Use SETUP>COMM>INET to configure Ethernet communications, whether manually or via DHCP. Please see Section 6.5 for configuration details.

5.7.3. COM1 AND COM2 (MODE, BAUD RATE AND TEST PORT)

Use the SETUP>COMM>COM1[COM2] menus to:

- configure communication modes (Section 6.2.1)

- view/set the baud rate (Section 6.2.2)

- test the connections of the com ports (Section 6.2.3).

Configuring COM1 or COM2 requires setting the DCE DTE switch on the rear panel. Section 6.1 provides DCE DTE information.

5.8. SETUP – VARS: VARIABLES SETUP AND DEFINITION

Through the SETUP>MORE>VARS menu there are several-user adjustable software variables that define certain operational parameters. Usually, these variables are automatically set by the instrument's firmware, but can be manually re-defined using the VARS menu. Table 5-2 lists all variables that are available within the 818 password protected level.

Table 5-2: Variable Names (VARS) Revision 1.0.3

NO.	VARIABLE	DESCRIPTION	ALLOWED VALUES
0	**DAS_HOLD_OFF**	Changes the internal data acquisition system (DAS) hold-off time, which is the duration when data are not stored in the DAS because the software considers the data to be questionable. That is the case during warm-up or just after the instrument returns from one of its calibration modes to SAMPLE mode. DAS_HOLD_OFF can be disabled entirely in each DAS channel.	Can be between 0.5 and 20 minutes Default=15 min.
1	**TPC_ENABLE**	Enables or disables the temperature and pressure compensation (TPC) feature (refer to Section 13.7.3).	ON/OFF
2	**RCELL_SET**	Sets the sample chamber temperature. Increasing or decreasing this temperature will increase or decrease the rate at which SO_2^* decays into SO_2 (refer to Section 13.1.1). Do not adjust this setting unless under the direction of Teledyne API Technical Support personnel.	30º C - 70º C Default= 50º C
3	**IZS_SET**	Sets the IZS option temperature. Increasing or decreasing this temperature will increase or decrease the permeation rate of the IZS source (refer to Sections 3.3.2.4, 9.5, 9.6).	30º C - 70º C Default= 50º C
4	**DYN_ZERO**	Dynamic zero automatically adjusts offset and slope of the SO_2 response when performing a zero point calibration during an AutoCal (refer to Section 9).	ON/OFF
5	**DYN_SPAN**	Dynamic span automatically adjusts slope and slope of the SO_2 response when performing a zero point calibration during an AutoCal (refer to Section 9). Note that the DYN_ZERO and DYN_SPAN features are not allowed for applications requiring EPA equivalency.	ON/OFF
6	**CONC_PRECISION**	Allows the user to set the number of significant digits to the right of the decimal point display of concentration and stability values.	AUTO, 1, 2, 3, 4 Default=AUTO
7	**CLOCK_ADJ**	Adjusts the speed of the analyzer's clock. Choose the + sign if the clock is too slow, choose the - sign if the clock is too fast.	-60 to +60 s/day
8	**SERVICE_CLEAR**	ON resets the service interval timer. Returns to OFF upon reset.	ON/OFF
9	**TIME_SINCE_SVC**	Number of hours since last service.	0-500000
10	**SVC_INTERVAL**	Sets the intval between service reminders.	0-100000

IMPORTANT   **IMPACT ON READINGS OR DATA**

There are more VARS available when using the password, 929, for configuration. Use caution when pressing any buttons while in this setup. Any changes made may alter the performance of the instrument or cause the instrument to not function properly. Note that if there is an accidental change to a setup parameter, press EXIT to discard the changes.

To access and navigate the VARS menu, use the following button sequence.
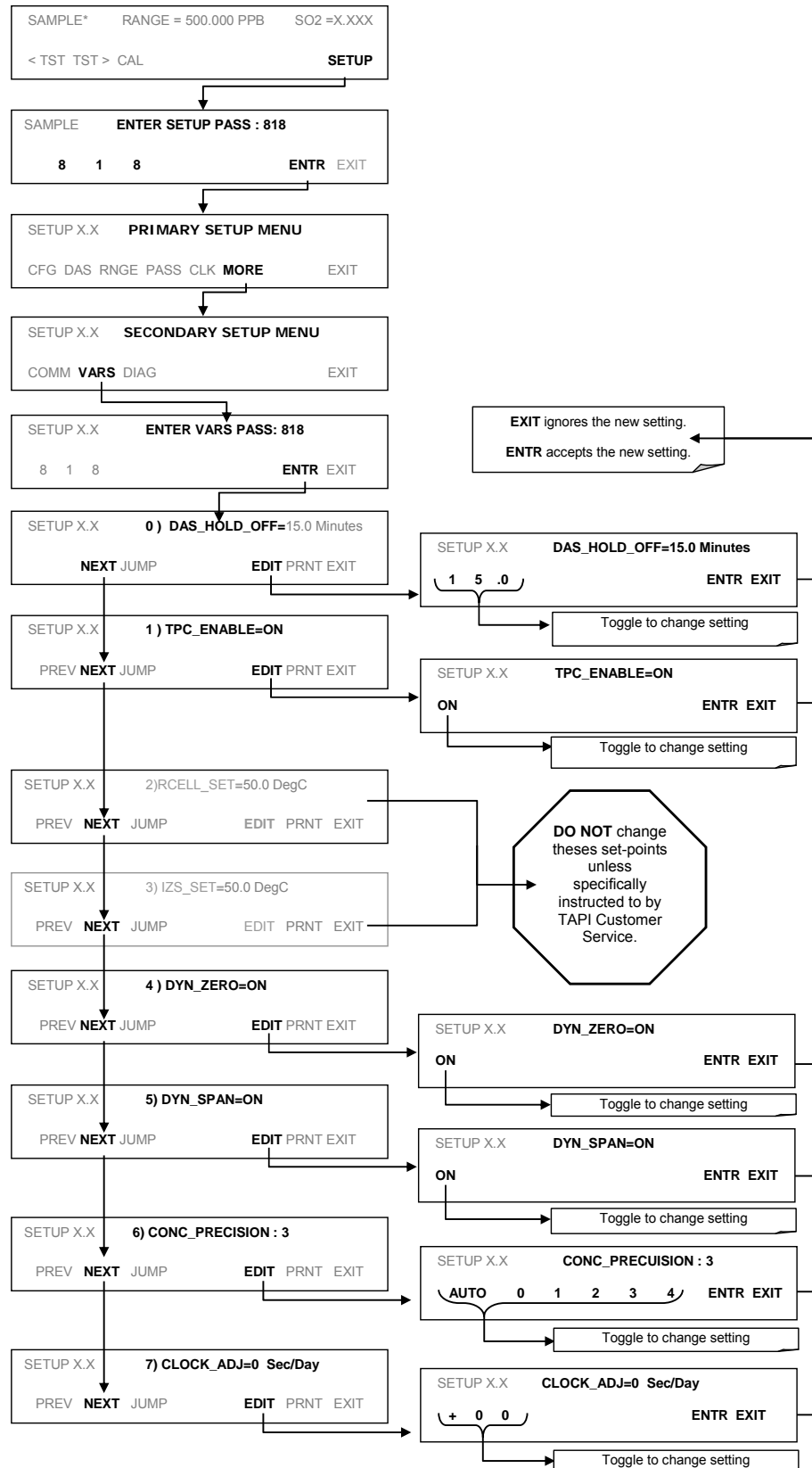
Figure 5-15:   SETUP – VARS Menu

5.9. SETUP – DIAG: DIAGNOSTICS FUNCTIONS

The SETUP>MORE>DIAG menu provides a series of diagnostic functions whose parameters are dependent on firmware revision (refer to Menu Tree, A-5, in Appendix A). Table 5-3 describes the functions and provides a cross-reference to the details for each in the remainder of this section. These functions can be used as tools in a variety of troubleshooting and diagnostic procedures.

Table 5-3: T100 Diagnostic (DIAG) Functions

DIAGNOSTIC FUNCTION AND MEANING	FRONT PANEL MODE INDICATOR	SECTION
SIGNAL I/O: Allows observation of all digital and analog signals in the instrument. Allows certain digital signals such as valves and heaters to be toggled ON and OFF.	**DIAG I/O**	5.9.1
ANALOG OUTPUT: When entered, the analyzer performs an analog output step test. This can be used to calibrate a chart recorder or to test the analog output accuracy.	**DIAG AOUT**	5.9.2
ANALOG I/O CONFIGURATION: Analog input/output parameters are available for viewing and configuration.	**DIAG AIO**	5.9.3
OPTIC TEST: When activated, the analyzer performs an optic test, which turns on an LED located inside the sensor module near the PMT (Fig. 10-15). This diagnostic tests the response of the PMT without having to supply span gas.	**DIAG OPTIC**	5.9.4
ELECTRICAL TEST: When activated, the analyzer performs an electric test, which generates a current intended to simulate the PMT output to verify the signal handling and conditioning of the PMT preamp board.	**DIAG ELEC**	5.9.5
LAMP CALIBRATION: The analyzer records the current voltage output of the UV source reference detector. This value is used by the CPU to calculate the lamp ration used in determining the SO_2 concentration	**DIAG LAMP**	5.9.6
PRESSURE CALIBRATION: The analyzer records the current output of the sample gas pressure sensor. This value is used by the CPU to compensate the SO_2 concentration when the TPC feature is enabled.	**DIAG PCAL**	5.9.7
FLOW CALIBRATION: This function is used to calibrate the gas flow output signals of sample gas and ozone supply. These settings are retained when exiting DIAG.	**DIAG FCAL**	5.9.8
TEST CHAN OUTPUT: Configures the A4 analog output channel.	**DIAG TCHN**	5.9.9

To access the **DIAG** functions press the following buttons:
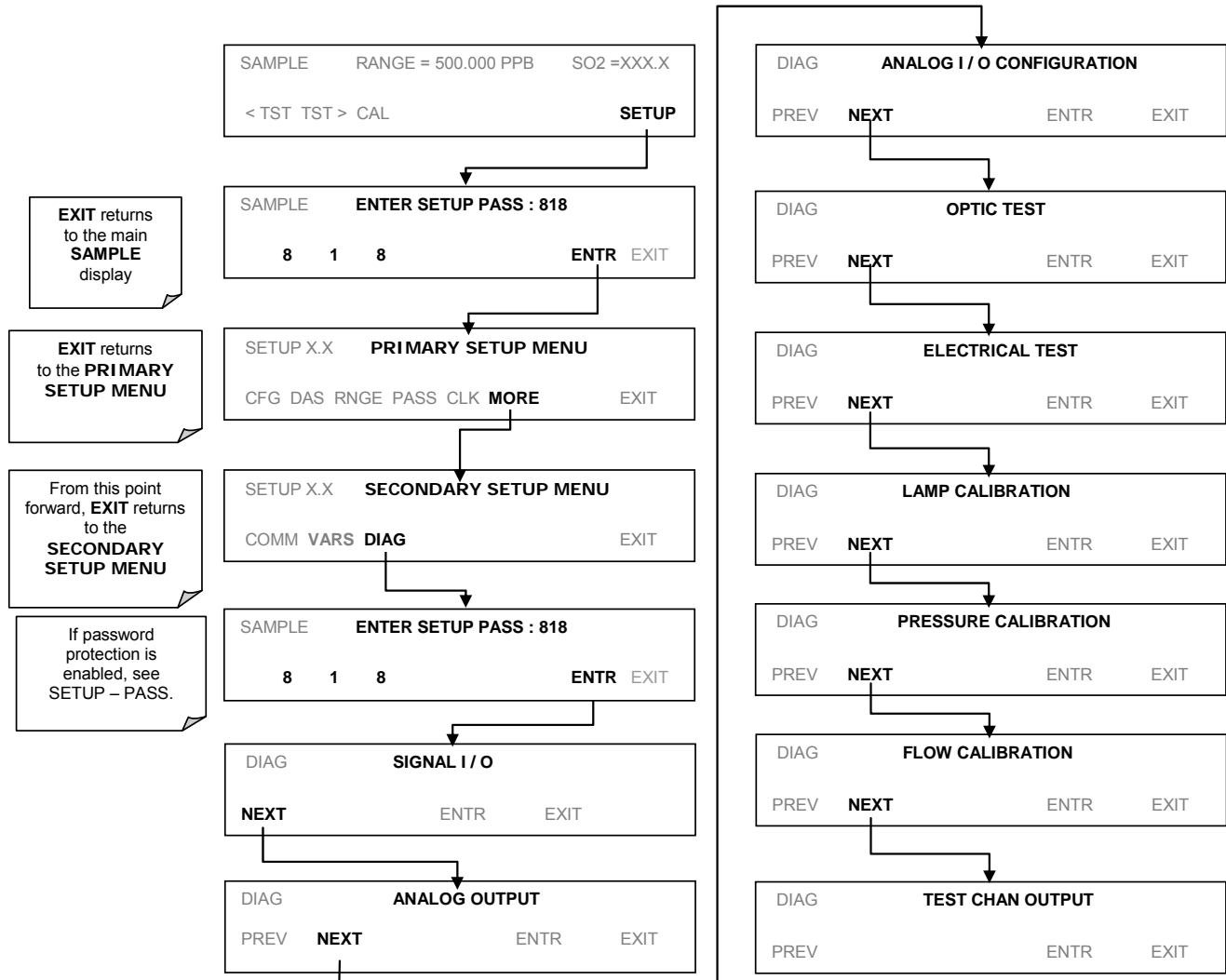
Figure 5-16:   DIAG Menu

5.9.1. SIGNAL I/O

The signal I/O diagnostic mode allows a user to review and change the digital and analog input/output functions of the analyzer. Refer to Appendix A-4 for a complete list of the parameters available for review under this menu.

IMPORTANT

IMPACT ON READINGS OR DATA
Any changes of signal I/O settings will remain in effect only until the signal I/O menu is exited. Exceptions are the ozone generator override and the flow sensor calibration, which remain as entered when exiting.

Access the signal I/O test mode from the DIAG Menu (refer to Figure 5-16), then press:
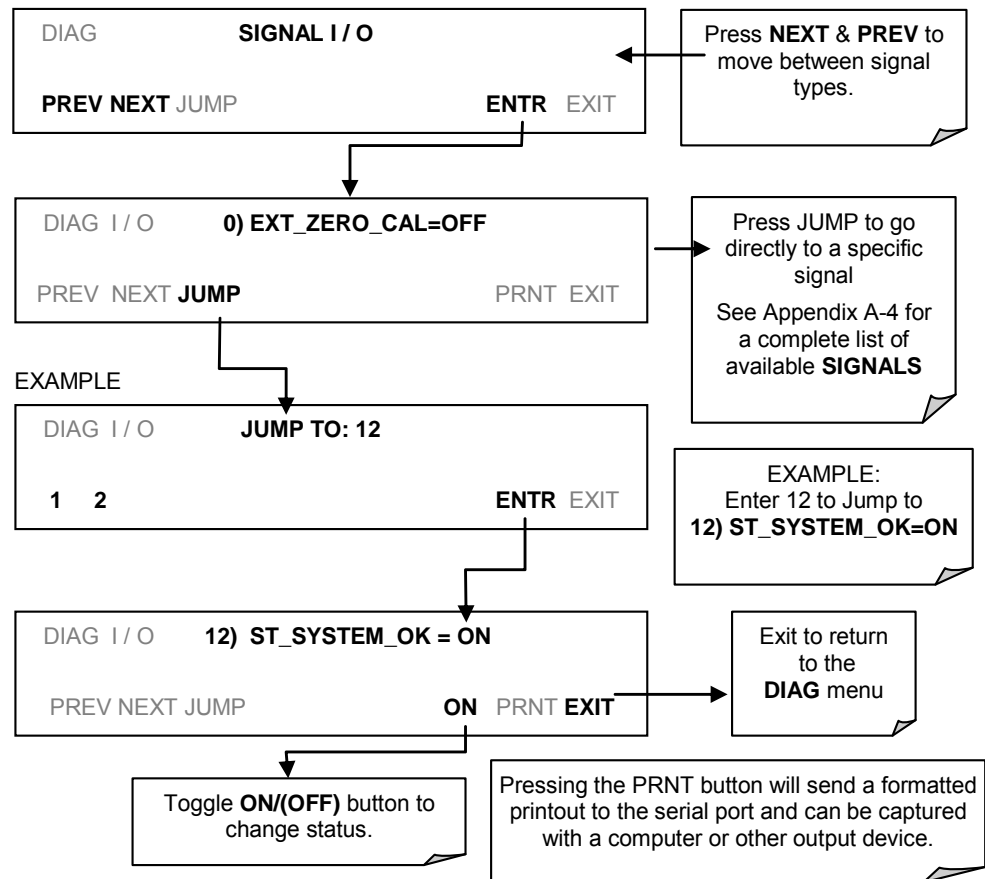
Figure 5-17:   DIAG – Signal I/O Menu

5.9.2. ANALOG OUTPUT STEP TEST

Analog Output is used as a step test to check the accuracy and proper operation of the analog outputs. The test forces all four analog output channels to produce signals ranging from 0% to 100% of the full scale range in 20% increments. This test is useful to verify the operation of the data logging/recording devices attached to the analyzer.

Access the Analog Output Step Test from the DIAG Menu (refer to Figure 5-16), then press:
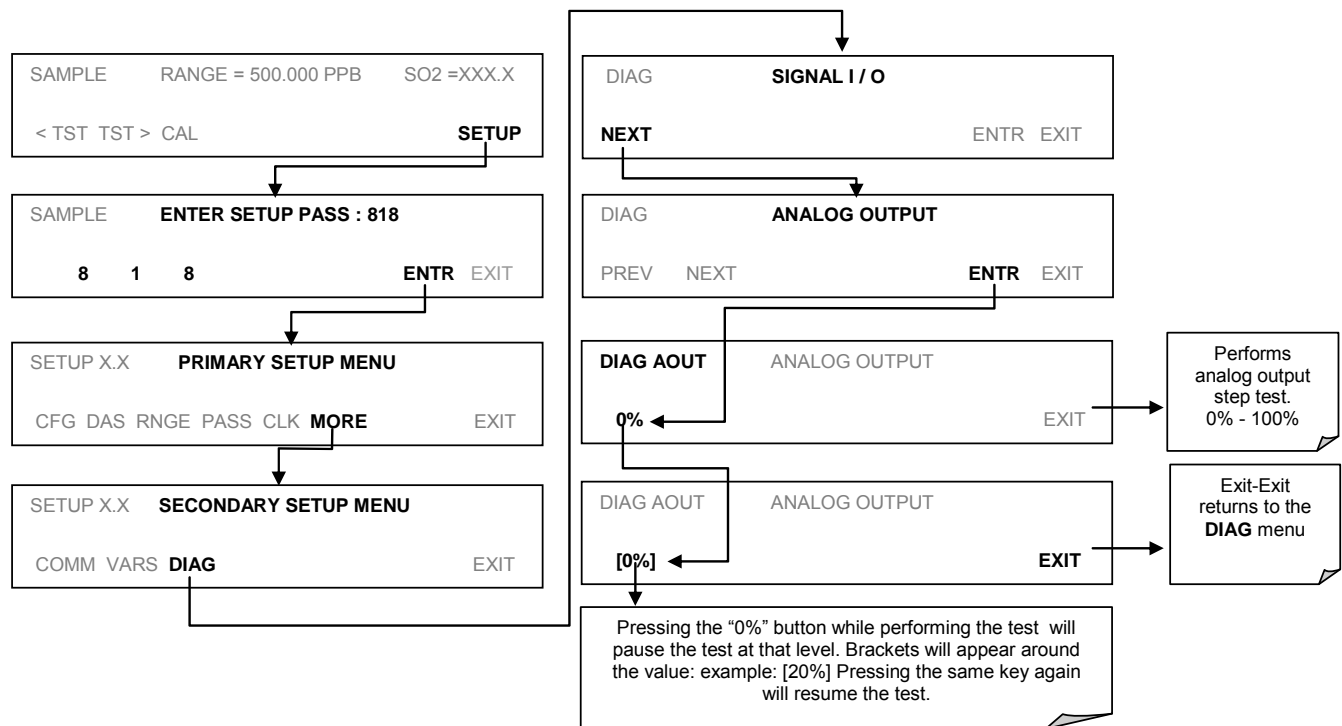
Figure 5-18:   DIAG – Analog Output Menu

5.9.3. ANALOG I/O CONFIGURATION

Table 6-8 lists the analog I/O functions that are available in the T100.

Table 5-4: DIAG - Analog I/O Functions

SUB MENU	FUNCTION
AOUTS CALIBRATED:	Shows the status of the analog output calibration (YES/NO) and initiates a calibration of all analog output channels.
CONC_OUT_1	Sets the basic electronic configuration of the A1 analog output (SO$_2$). There are three options: • **RANGE:** Selects the signal type (voltage or current loop) and full scale level of the output. • **REC_OFS:** Allows setting a voltage offset (not available when RANGE is set to Current Loop (**CURR**). • **AUTO_CAL:** Performs the same calibration as AOUT CALIBRATED, but on this one channel only. NOTE: Any change to RANGE or REC_OFS requires recalibration of this output.
CONC_OUT_2	Same as for CONC_OUT_1 but for analog channel 2 (SO$_2$)
TEST OUTPUT	Same as for CONC_OUT_1 but for analog channel 3 (TEST)
CONC_OUT_3	(Not available in the analyzer's standard configuration; applies when optional sensor installed).
AIN CALIBRATED	Shows the calibration status (YES/NO) and initiates a calibration of the analog input channels.
XIN1 . . . XIN8	For each of 8 external analog inputs channels, shows the gain, offset, engineering units, and whether the channel is to show up as a Test function.

Table 5-5: Analog Output Voltage Ranges

RANGE	MINIMUM OUTPUT	MAXIMUM OUTPUT
0-0.1 V	-5 mV	+105 mV
0-1 V	-0.05 V	+1.05 V
0-5 V	-0.25 V	+5.25 V
0-10 V	-0.5 V	+10.5 V
The default offset for all ranges is 0 VDC.		

The following DC current output limits apply to the current loop modules:

Table 5-6: Analog Output Current Loop Range

RANGE	MINIMUM OUTPUT	MAXIMUM OUTPUT
0-20 mA	0 mA	20 mA
These are the physical limits of the current loop modules, typical applications use 2-20 or 4-20 mA for the lower and upper limits. Please specify desired range when ordering this option. The default offset for all ranges is 0 mA.		
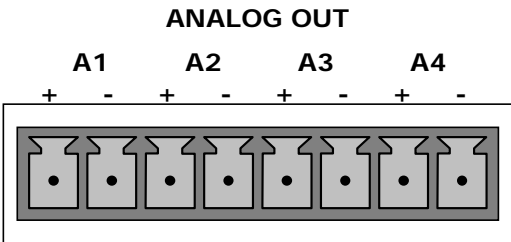
ANALOG OUT

Refer to Figure 3-4 for the location of the analog output connector on the instrument's rear panel and Table 3-6 for pin assignments.

5.9.3.1. **ANALOG OUTPUT SIGNAL TYPE AND RANGE SPAN SELECTION**

To select an output signal type (DC Voltage or current) and level for one output channel, activate the **ANALOG I/O CONFIGURATION MENU** from the **DIAG** Menu (refer to Figure 5-16), then press:

DIAG	**ANALOG I / O CONFIGURATION**		
PREV	NEXT	**ENTR**	EXIT

DIAG AIO	AOUTS CALIBRATED: NO	
< SET **SET>**	CAL	EXIT

> Press **SET>** to select the analog output channel to be configured. Press **EDIT** to continue

DIAG AIO	**CONC_OUT_1:5V,OVR,CAL**	
< SET SET>	**EDIT**	EXIT

DIAG AIO	**CONC_OUT_1 RANGE: 5V**	
SET>	**EDIT**	EXIT

DIAG AIO	**CONC_OUT_1 RANGE: 5V**		
0.1V 1V 5V **10V** CURR		ENTR EXIT

> These buttons set the signal level and type for the selected channel

DIAG AIO	**CONC_OUT_1 RANGE: 10V**	
0.1V 1V 5V **10V** CURR	**ENTR EXIT**

> Pressing **ENTR** records the new setting and returns to the previous menu. Pressing **EXIT** ignores the new setting and returns to the previous menu.

Figure 5-19:   DIAG – Analog I/O Configuration Menu

5.9.3.2. **ANALOG OUTPUT CALIBRATION MODE**

Analog output calibration should to be carried out on first startup of the analyzer (performed in the factory as part of the configuration process) or whenever recalibration is required. The analog outputs can be calibrated automatically, either as a group or individually, or adjusted manually.

In its default mode, the instrument is configured for automatic calibration of all channels, which is useful for clearing any analog calibration warnings associated with channels that will not be used or connected to any input or recording device, e.g., datalogger.

Manual calibration should be used for the 0.1V range or in cases where the outputs must be closely matched to the characteristics of the recording device. Manual calibration requires the AUTOCAL feature to be disabled.

To calibrate the outputs as a group, activate the **ANALOG I/O CONFIGURATION MENU** from the DIAG Menu (refer to Figure 5-16), then press:
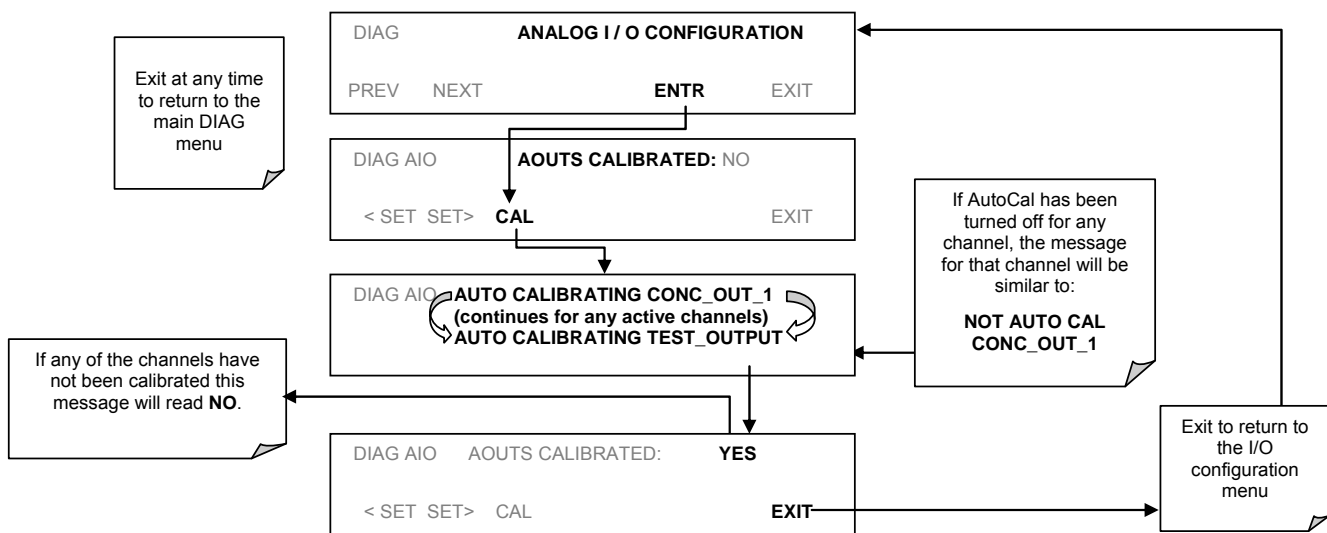
Figure 5-20:   DIAG – Analog Output Calibration Mode

To automatically calibrate a single analog channel from the DIAG Menu (refer to Figure 5-16), press:
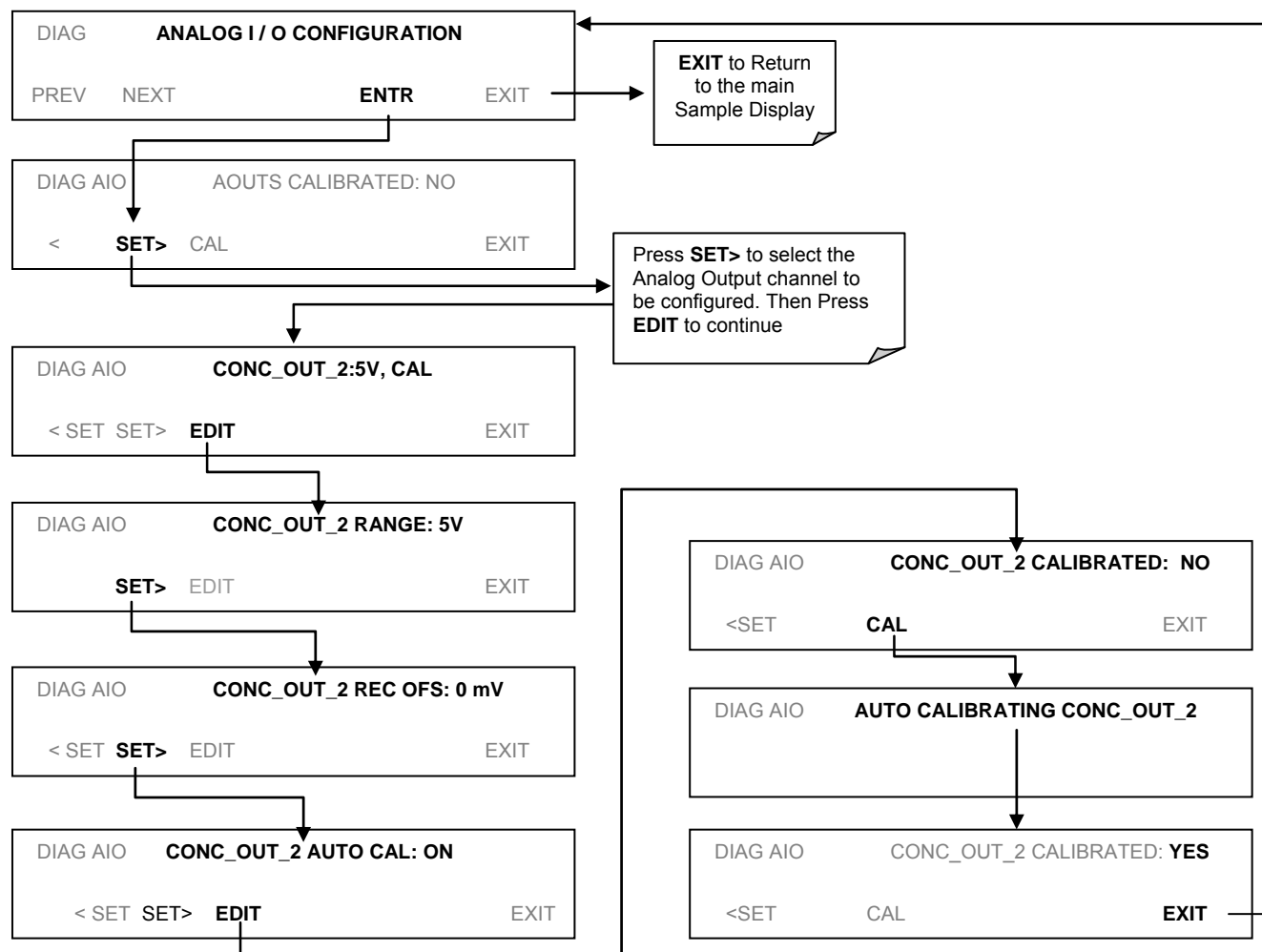
Figure 5-21:   DIAG – Analog Output Calibration Mode – Single Analog Channel

To select manual output calibration for a particular channel, access the Analog I/O Configuration from the DIAG Menu (refer to Figure 5-16), then press:
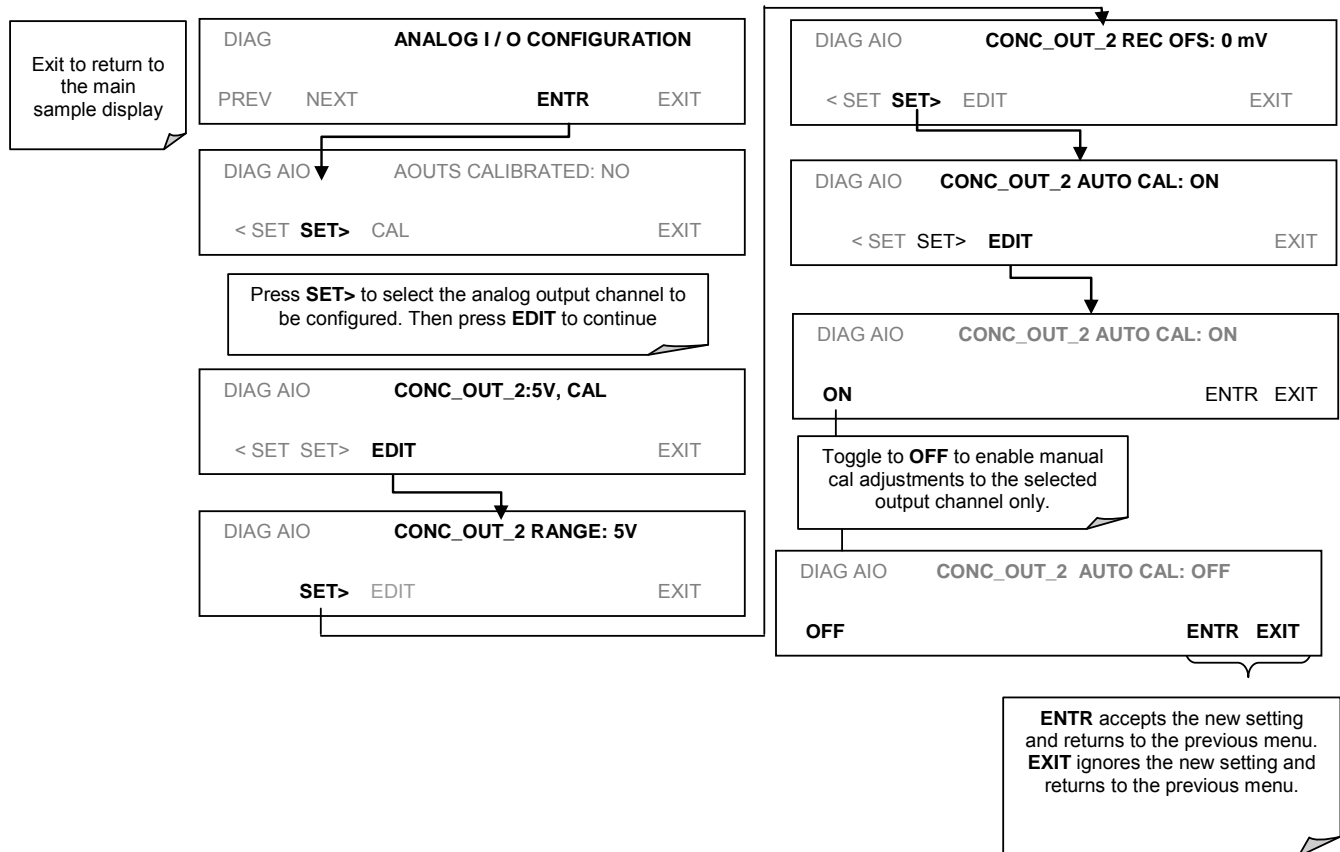
Figure 5-22:   DIAG – Analog Output – Auto Cal or Manual Cal Selection for Channels

Now the analog output channels should either be automatically calibrated or they should be set to manual calibration, which is described next.

5.9.3.3. **MANUAL ANALOG OUTPUT CALIBRATION AND VOLTAGE ADJUSTMENT**

For highest accuracy, the voltages of the analog outputs can be manually calibrated. Calibration is done through the instrument software with a voltmeter connected across the output terminals (refer to Figure 5-23). Adjustments are made using the control buttons by setting the zero-point first and then the span-point (refer to Table 5-7).

The software allows this adjustment to be made in 100, 10 or 1 count increments.

Table 5-7: Voltage Tolerances for Analog Output Calibration

FULL SCALE	ZERO TOLERANCE	SPAN VOLTAGE	SPAN TOLERANCE
0.1 VDC	±0.0005V	90 mV	±0.001V
1 VDC	±0.001V	900 mV	±0.001V
5 VDC	±0.002V	4500 mV	±0.003V
10 VDC	±0.004V	4500 mV	±0.006V

IMPORTANT

IMPACT ON READINGS OR DATA

Outputs configured for 0.1V full scale should always be calibrated manually.
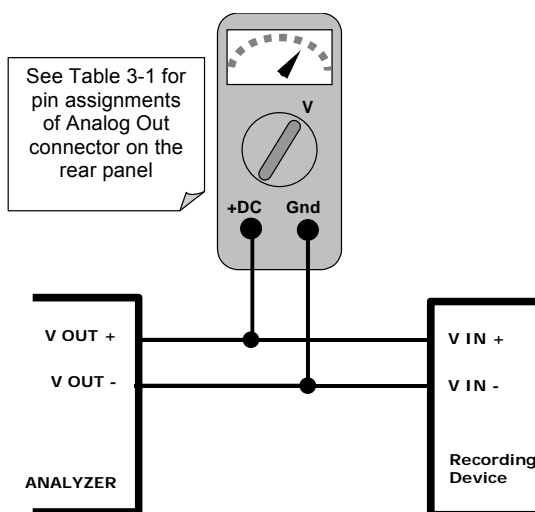
Figure 5-23:   Setup for Calibrating Analog Outputs

To make these manual adjustments, the **AOUT** auto-calibration feature must be turned **OFF** (refer to Section 5.9.3.2). Activate the **ANALOG I/O CONFIGURATION MENU** from the DIAG Menu (refer to Figure 5-16), then press:
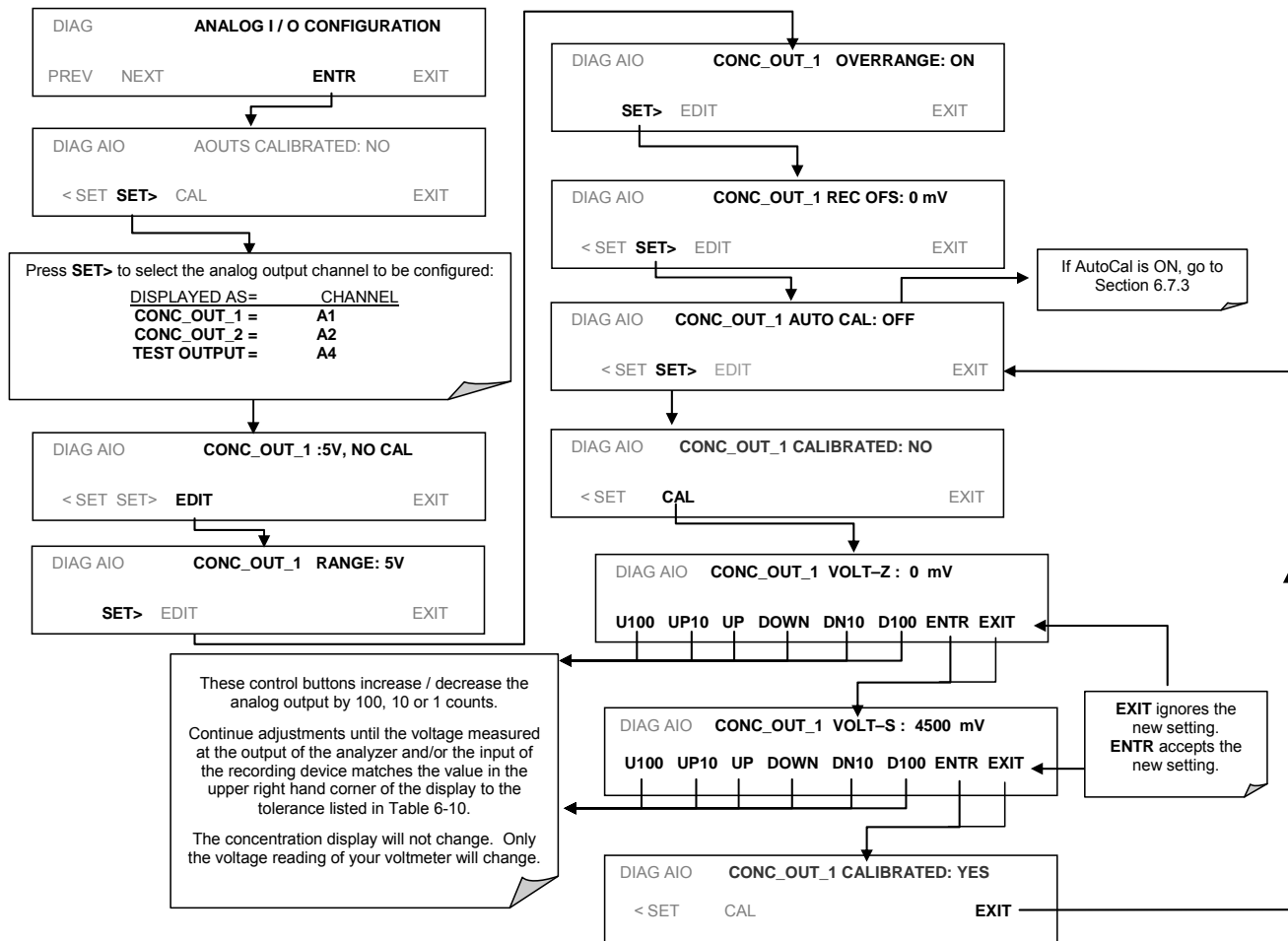
Figure 5-24: **Analog Output – Voltage Adjustment**

5.9.3.4. **ANALOG OUTPUT OFFSET ADJUSTMENT**

Some analog signal recorders require that the zero signal to be significantly different from the baseline of the recorder in order to record slightly negative readings from noise around the zero point. This can be achieved in the T100 by defining a zero offset, a small voltage (e.g., 10% of span), which can be added to the signal of individual output channels by activating the **ANALOG I/O CONFIGURATION MENU** from the DIAG Menu (refer to Figure 5-16), then press:
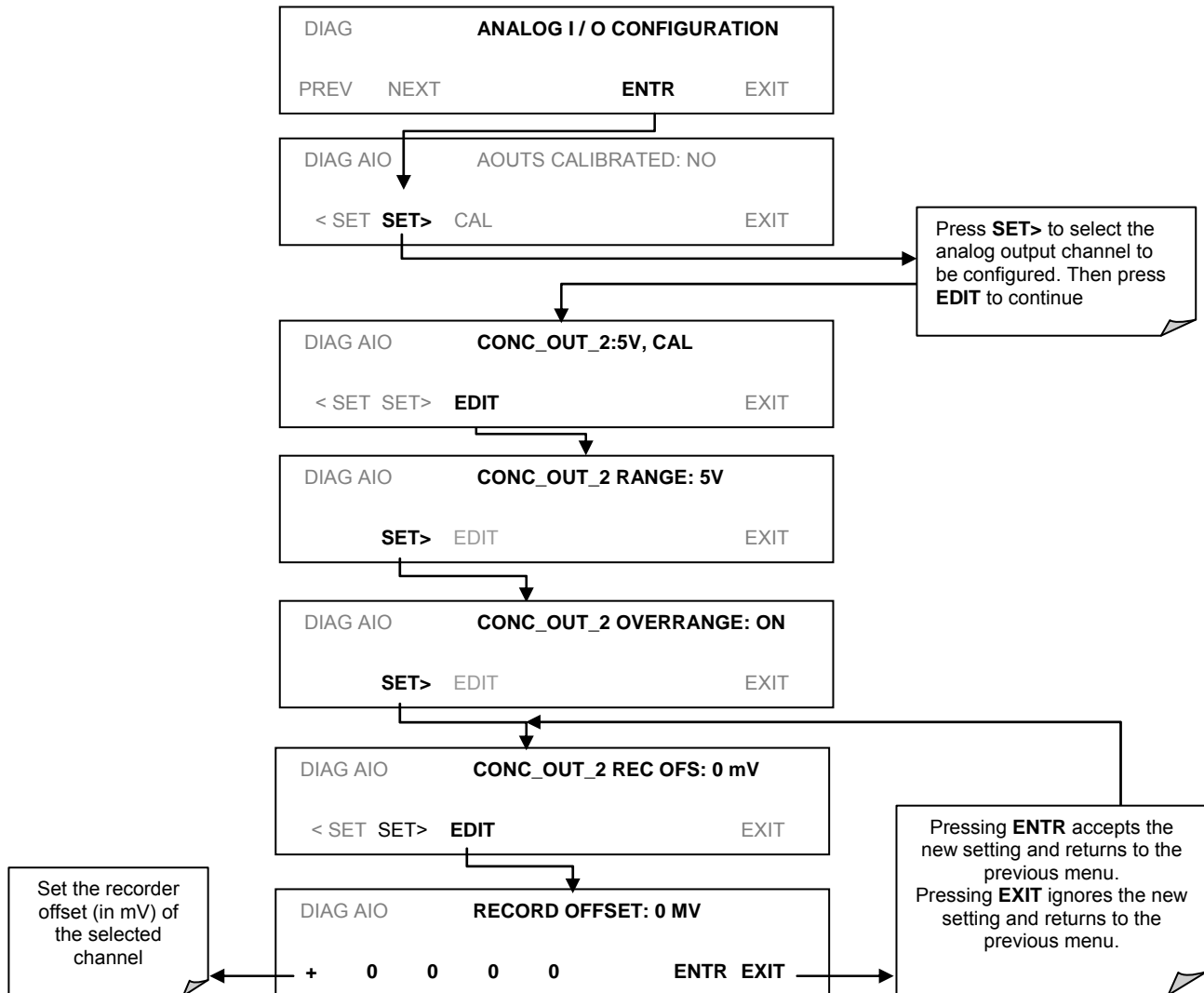
Figure 5-25:   Analog Output – Offset Adjustment

5.9.3.5. **CURRENT LOOP OUTPUT ADJUSTMENT**

A current loop option is available and can be installed as a retrofit for each of the analog outputs of the analyzer (refer to Section 3.3.1.4). This option converts the DC voltage analog output to a current signal with 0-20 mA output current. The outputs can be scaled to any set of limits within that 0-20 mA range. However, most current loop applications call for either 2-20 mA or 4-20 mA range. All current loop outputs have a +5% over-range. Ranges with the lower limit set to more than 1 mA (e.g., 2-20 or 4-20 mA) also have a -5% under-range.

To switch an analog output from voltage to current loop after installing the current output printed circuit assembly, follow the instructions in Section 6.9.4.1 and select **CURR** from the list of options on the "Output Range" menu.

Adjusting the signal zero and span values of the current loop output is done by raising or lowering the voltage of the respective analog output. This proportionally raises or lowers the current produced by the current loop option.

Similar to the voltage calibration, the software allows this current adjustment to be made in 100, 10 or 1 count increments. Since the exact current increment per voltage count varies from output to output and from instrument to instrument, you will need to measure the change in the current with a current meter placed in series with the output circuit (refer to Figure 5-26).
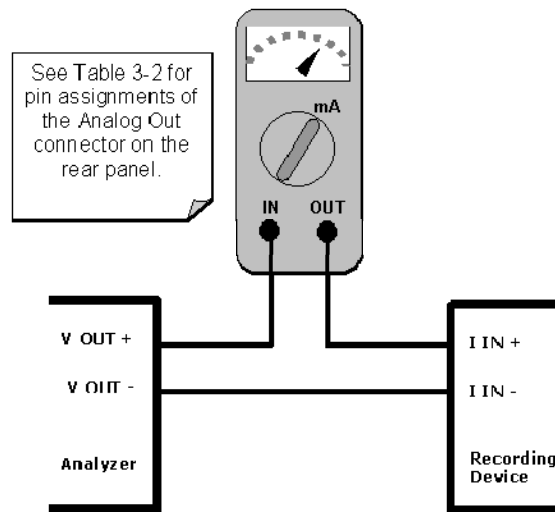
Figure 5-26:   Setup for Calibrating Current Outputs

WARNING

Do not exceed 60 V between current loop outputs and instrument ground.

To adjust the zero and span values of the current outputs, activate the **ANALOG I/O CONFIGURATION MENU** from the DIAG Menu (refer to Figure 5-16), then press:
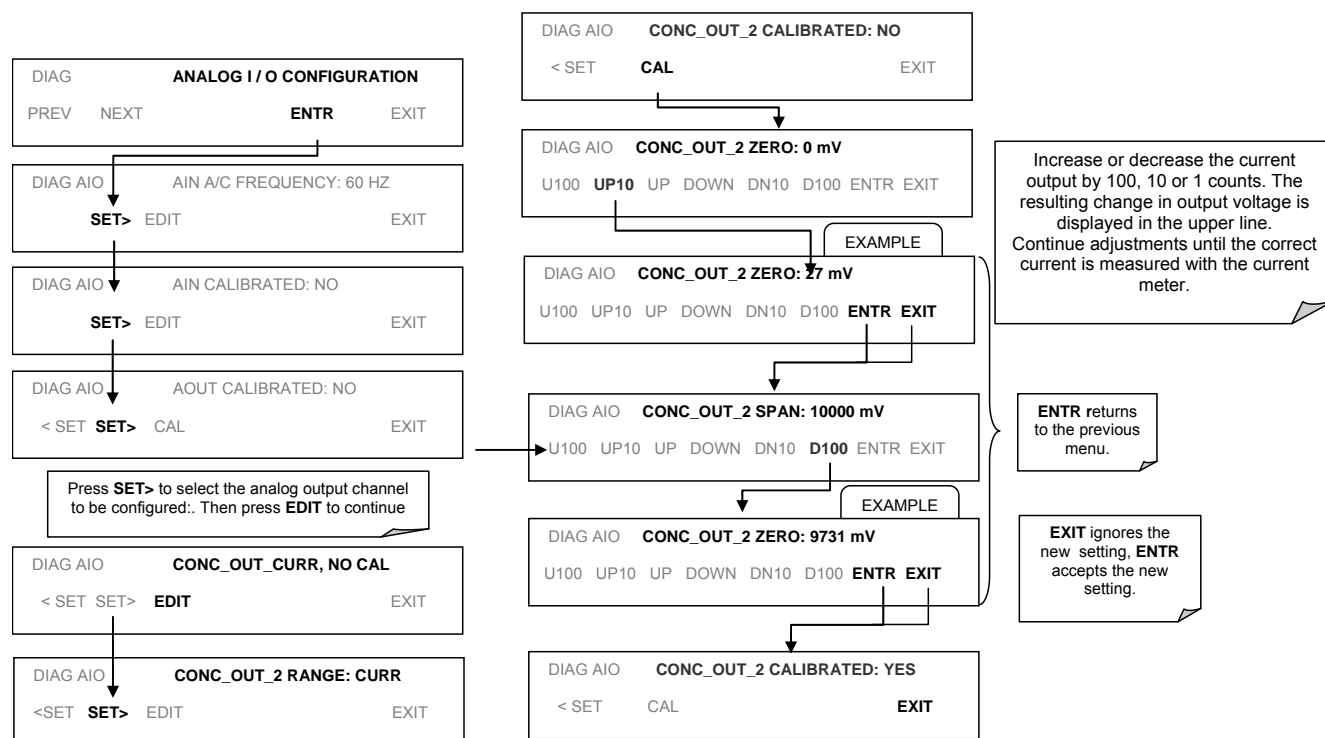
Figure 5-27:   Analog Output – Zero and Span Value Adjustment for Current Outputs

If a current meter is not available, an alternative method for calibrating the current loop outputs is to connect a 250 Ω ±1% resistor across the current loop output. Using a voltmeter, connected across the resistor, follow the procedure above but adjust the output to the following values:

Table 5-8: Current Loop Output Calibration with Resistor

FULL SCALE	VOLTAGE FOR 2-20 MA (MEASURED ACROSS RESISTOR)	VOLTAGE FOR 4-20 MA (MEASURED ACROSS RESISTOR)
0%	0.5 V	1.0 V
100%	5.0 V	5.0 V

5.9.3.6. **AIN CALIBRATION**

This is the sub-menu to conduct the analog input calibration. This calibration should only be necessary after major repair such as a replacement of CPU, motherboard or power supplies. Navigate to the **ANALOG I/O CONFIGURATION MENU** from the DIAG Menu (refer to Figure 5-16), then press:
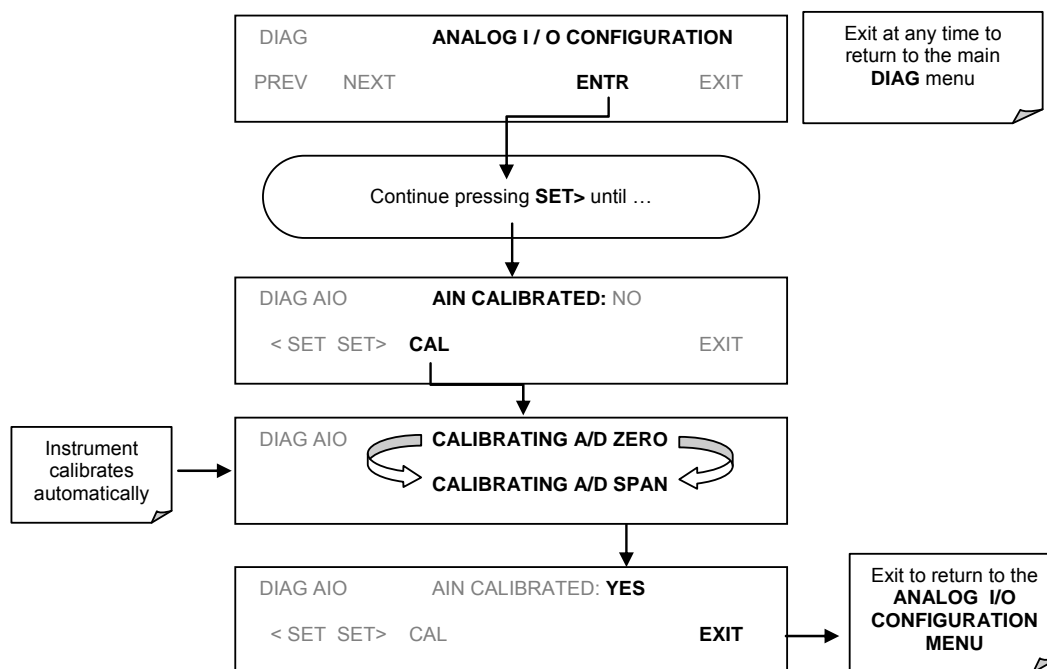
Figure 5-28:   DIAG – Analog Output – AIN Calibration

5.9.3.7. **ANALOG INPUTS (XIN1…XIN8) OPTION CONFIGURATION**

To configure the analyzer' **optional analog inputs** define for each channel**:**

- gain (number of units represented by 1 volt)

- offset (volts)

- engineering units to be represented in volts (each press of the touchscreen button scrolls the list of alphanumeric characters from A-Z and 0-9)

- whether to display the channel in the Test functions

To adjust settings for the Analog Inputs option parameters press:
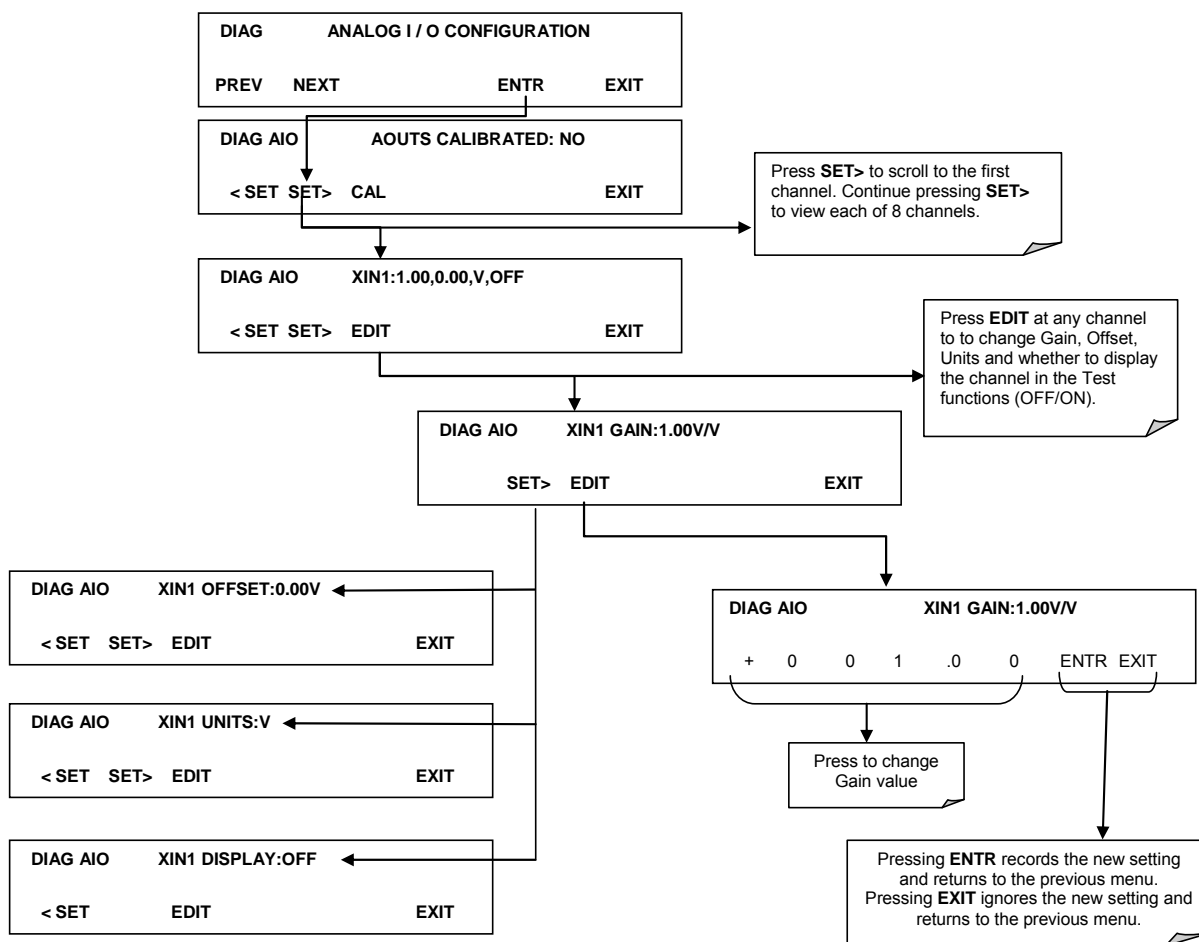
Figure 5-29.   DIAG – Analog Inputs (Option) Configuration Menu

5.9.4. OPTIC TEST

The optic test function tests the response of the PMT sensor by turning on an LED located in the cooling block of the PMT (refer to Figure 13-18). The analyzer uses the light emitted from the LED to test its photo-electronic subsystem, including the PMT and the current to voltage converter on the pre-amplifier board. To ensure that the analyzer measures only the light coming from the LED, the analyzer should be supplied with zero air. The optic test should produce a PMT signal of about 2000±1000 mV.

Access the Optic Test from the DIAG Menu (refer to Figure 5-16), then press:
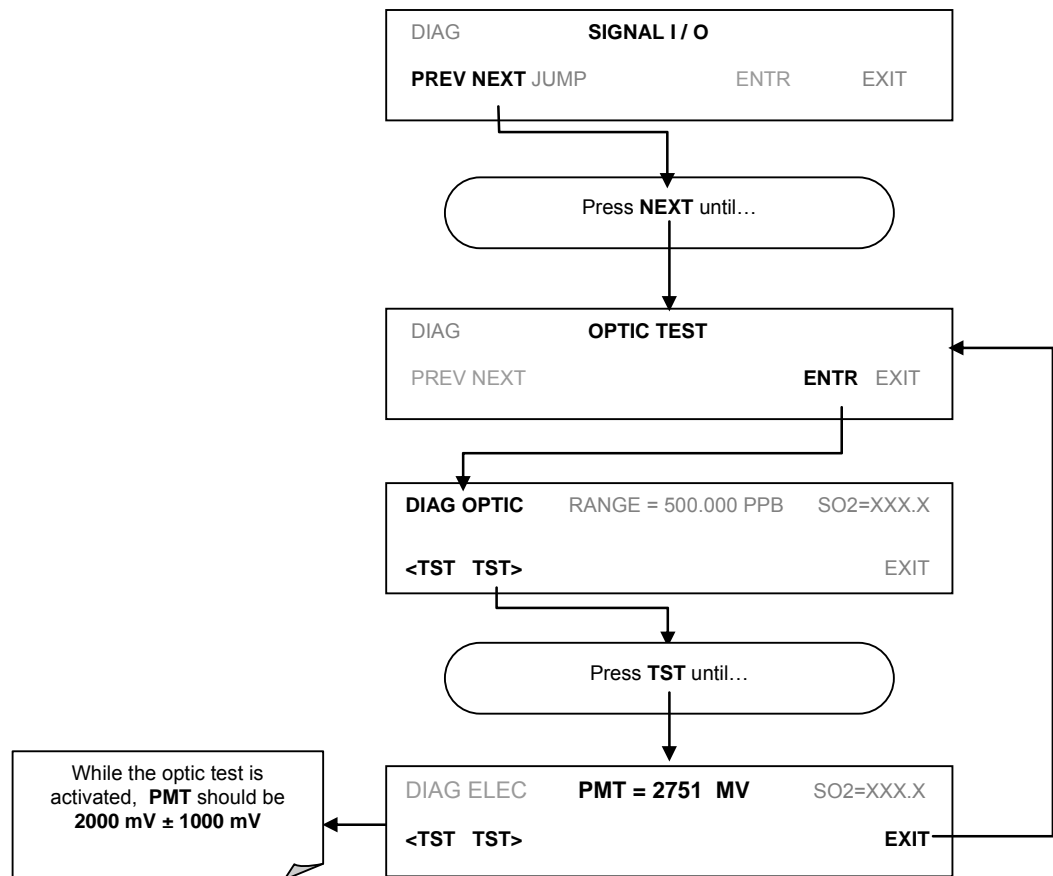
Figure 5-30:   DIAG – Optic Test

IMPORTANT   **IMPACT ON READINGS OR DATA**
This is a coarse test for functionality and not an accurate calibration tool. The resulting PMT signal can vary significantly over time and also changes with low-level calibration.

5.9.5. ELECTRICAL TEST

The electrical test function creates a current, which substitutes the PMT signal, and feeds it into the preamplifier board. This signal is generated by circuitry on the pre-amplifier board itself and tests the filtering and amplification functions of that assembly along with the A/D converter on the motherboard. It does not test the PMT itself. The electrical test should produce a PMT signal of about 2000 ±1000 mV.

Access the Electrical Test from the DIAG Menu (refer to Figure 5-16), then press:
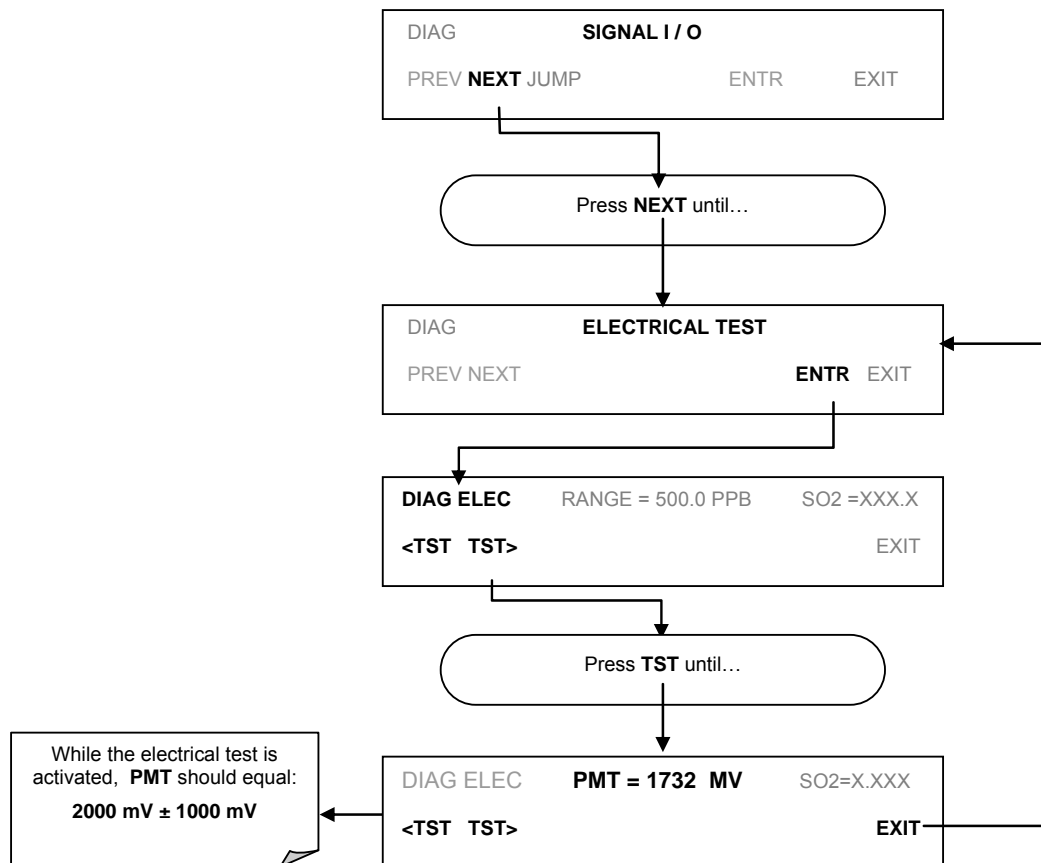
Figure 5-31:   DIAG – Electrical Test

5.9.6. LAMP CALIBRATION

An important factor in accurately determining SO_2 concentration is the amount of UV light available to transform the SO_2 into SO_2^* (refer to Section 13.1.1). The T100 compensates for variations in the intensity of the available UV light by adjusting the SO_2 concentration calculation using a ratio (**LAMP RATIO**)that results from dividing the current UV lamp (**UV LAMP)** intensity by a value stored in the CPU's memory (**LAMP_CAL**). Both LAMP Ration and UV Lamp are test functions viewable from the instruments front panel.

To cause the analyzer to measure and record a value for **LAMP_CAL**, access the Signal I/O from the DIAG Menu (refer to Figure 5-16), then press:
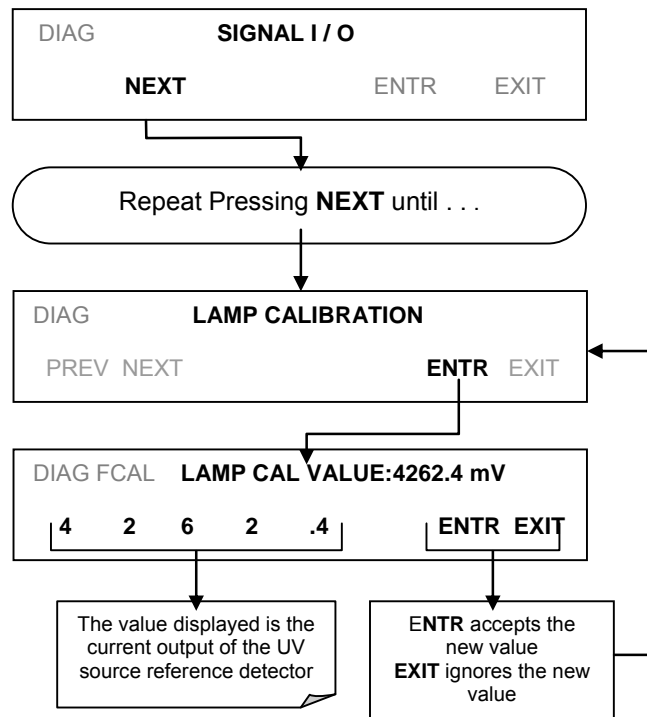
Figure 5-32:   DIAG – Lamp Calibration

5.9.7. PRESSURE CALIBRATION

A sensor at the exit of the sample chamber continuously measures the pressure of the sample gas. This data is used to compensate the final SO_2 concentration calculation for changes in atmospheric pressure when the instrument's TPC feature is turned on (refer to Section 10.7.3) and is stored in the CPU's memory as the test function **PRES** (also viewable via the front panel).

Ensure to use a barometer that measures actual barometric pressure.

To cause the analyzer to measure and record a value for **PRES**, access the Signal I/O from the DIAG Menu (refer to Figure 5-16), then press:
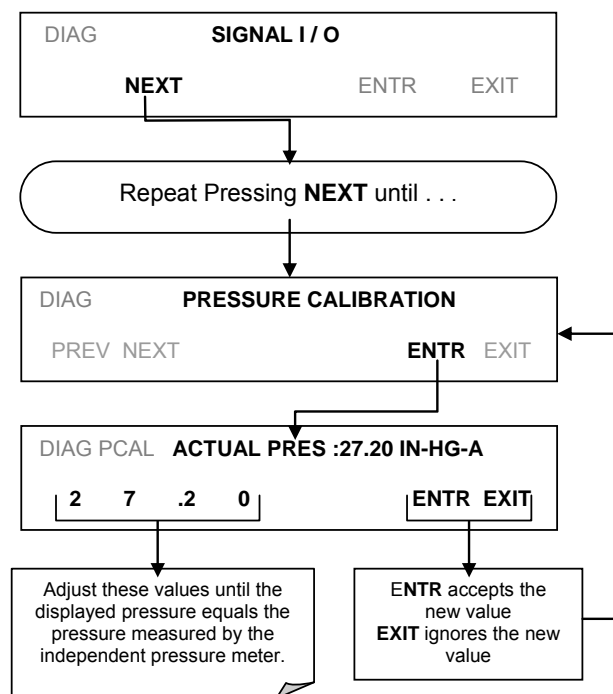
Figure 5-33:   DIAG – Pressure Calibration

5.9.8. FLOW CALIBRATION

The flow calibration allows the user to adjust the values of the sample flow rates as they are displayed on the front panel and reported through COM ports to match the actual flow rate measured at the sample inlet. This does not change the hardware measurement of the flow sensors, only the software calculated values.

To carry out this adjustment, connect an external, sufficiently accurate flow meter to the SAMPLE inlet (refer to Section 11 for more details).

Once the flow meter is attached and is measuring actual gas flow, access the Signal I/O from the DIAG Menu (refer to Figure 5-16), then press:
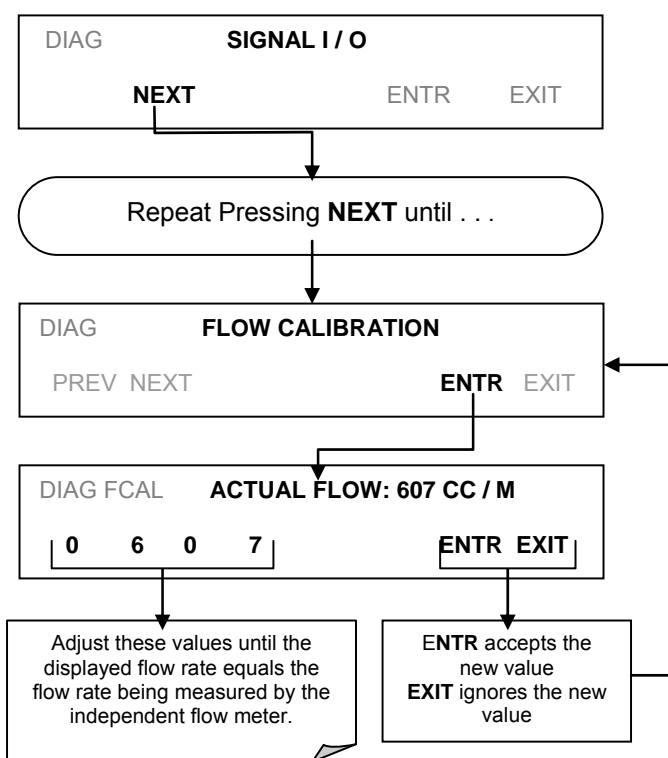
Figure 5-34:   **DIAG – Flow Calibration**

5.9.9. TEST CHANNEL OUTPUT

When activated, output channel **A3** can be used in the standard configuration to report one of the test functions viewable from the SAMPLE mode display.

To activate the **A3** channel and select a test function, access the Signal I/O from the DIAG Menu (refer to Figure 5-16), then press:
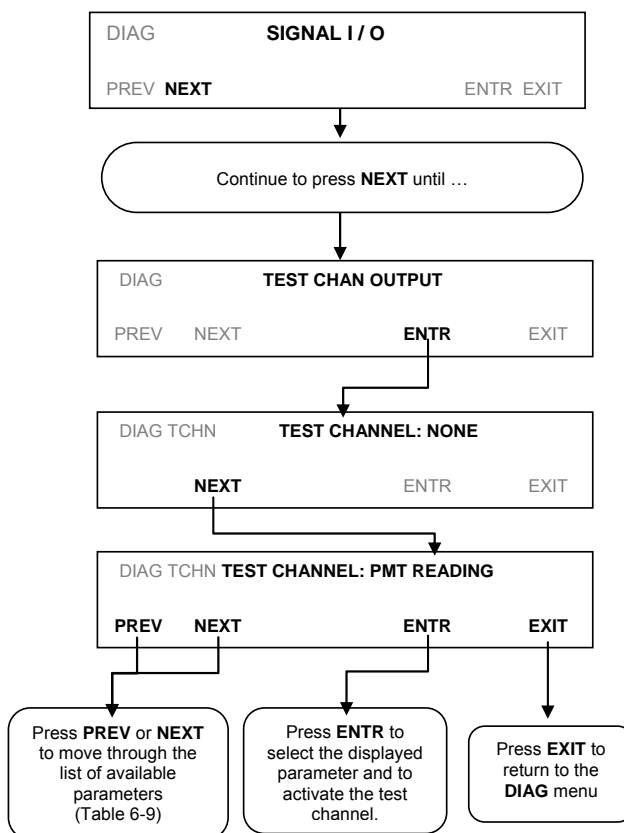
Figure 5-35:   DIAG – Test Channel Output

Table 5-9: Test Parameters Available for Analog Output A3 (standard configuration)

Test Channel	Test parameter range
NONE	Test channel is turned off
PMT READING	0-5000 mV
UV READING	0-5000 mV
SAMPLE PRESSURE	0-40 in-Hg-A
SAMPLE FLOW	0-1000 cm³/min
RCELL TEMP	0-70° C
CHASSIS TEMP	0-70° C
IZS TEMP	0-70° C
PMT TEMP	0-50° C
HVPS VOLTAGE	0-5000 V

Once a TEST function is selected, the instrument begins to report a signal on the **A3** output and adds **TEST** to the list of test functions viewable on the display (just before the **TIME** test function).

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6. COMMUNICATIONS SETUP AND OPERATION

This instrument rear panel connections include an Ethernet port, a USB port (option) and two serial communications ports (labeled **RS232**, which is the COM1 port, and **COM2**) located on the rear panel (refer to Figure 3-4). These ports give the user the ability to communicate with, issue commands to, and receive data from the analyzer through an external computer system or terminal.

This section provides pertinent information regarding communication equipment, describes the instrument's communications modes, presents configuration instructions for the communications ports, and provides instructions for their use, including communications protocol. Data acquisition is presented in Section .

6.1. DATA TERMINAL / COMMUNICATION EQUIPMENT (DTE DCE)

RS-232 was developed for allowing communications between data terminal equipment (DTE) and data communication equipment (DCE). Basic terminals always fall into the DTE category whereas modems are always considered DCE devices. The difference between the two is the pin assignment of the Data Receive and Data Transmit functions.

• DTE devices receive data on pin 2 and transmit data on pin 3.

• DCE devices receive data on pin 3 and transmit data on pin 2.

To allow the analyzer to be used with terminals (DTE), modems (DCE) and computers (which can be either), a switch mounted below the serial ports on the rear panel allows the user to set the RS-232 configuration for one of these two data devices. This switch exchanges the Receive and Transmit lines on RS-232 emulating a cross-over or null-modem cable. The switch has no effect on COM2.

6.2. COMMUNICATION MODES, BAUD RATE AND PORT TESTING

Use the SETUP>MORE>COMM menu to configure COM1 (labeled **RS232** on instrument rear panel) and/or COM2 (labeled **COM2** on instrument rear panel) for communication modes, baud rate and/or port testing for correct connection. If using a USB option communication connection, setup requires configuring the COM2 baud rate (Section 6.2.2).

6.2.1. COMMUNICATION MODES

Either of the analyzer's serial ports (**RS232** or **COM2** on rear panel) can be configured to operate in a number of different modes, which are described in .

Table 6-1: COMM Port Communication Modes

MODE[1]	ID	DESCRIPTION
QUIET	1	Quiet mode suppresses any feedback from the analyzer (DAS reports, and warning messages) to the remote device and is typically used when the port is communicating with a computer program such as APICOM. Such feedback is still available but a command must be issued to receive them.
COMPUTER	2	Computer mode inhibits echoing of typed characters and is used when the port is communicating with a computer program, such as APICOM.
HESSEN PROTOCOL	16	The Hessen communications protocol is used in some European countries. Teledyne API's part number 02252 contains more information on this protocol.
E, 7, 1	2048	Allows the **COMM** port settings to be set between either No parity; 8 data bits; 1 stop bit (ON/OFF) to Even parity; 7 data bits; 1 stop bit (ON/OFF)
RS-485	1024	Configures the **COM2** Port for RS-485 communication. RS-485 mode has precedence over Multidrop mode if both are enabled. When the COM2 port is configured for RS-485 communication, the rear panel USB port is disabled.
SECURITY	4	When enabled, the serial port requires a password before it will respond. The only command that is active is the help screen (? CR).
MULTIDROP PROTOCOL	32	Multidrop protocol allows a multi-instrument configuration on a single communications channel. Multidrop requires the use of instrument IDs.
ENABLE MODEM	64	Enables sending a modem initialization string at power-up. Asserts certain lines in the RS-232 port to enable the modem to communicate.
ERROR CHECKING[2]	128	Fixes certain types of parity errors at certain Hessen protocol installations.
XON/XOFF HANDSHAKE[2]	256	Disables XON/XOFF data flow control also known as software handshaking.
HARDWARE HANDSHAKE	8	Enables CTS/RTS style hardwired transmission handshaking. This style of data transmission handshaking is commonly used with modems or terminal emulation protocols as well as by Teledyne Instrument's APICOM software.
HARDWARE FIFO[2]	512	Improves data transfer rate when one of the COMM ports.
COMMAND PROMPT	4096	Enables a command prompt when in terminal mode.

[1] Modes are listed in the order in which they appear in the
   SETUP → MORE → COMM → COM[1 OR 2] → MODE menu

[2] The default setting for this feature is **ON.** Do not disable unless instructed to by Teledyne API's Technical Support personnel.

To turn on or off the communication modes for either COM1 or COM2, access the SETUP>MORE>[COM1 or COM2] menu and   at the COM1[2] Mode menu press EDIT.
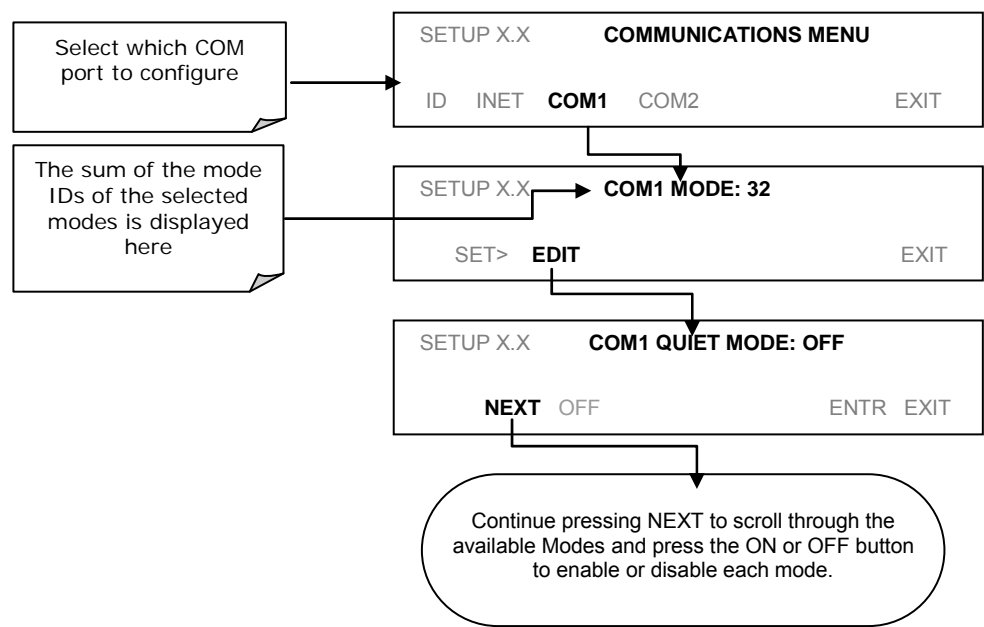
Figure 6-1: COMM – Communication Modes Setup

6.2.2. COMM PORT BAUD RATE

To select the baud rate of either COMM Port, go to SETUP>MORE>COMM and select either COM1 or COM2 as follows (use COM2 to view/match your personal computer baud rate when using the USB port, Section 6.5.3):
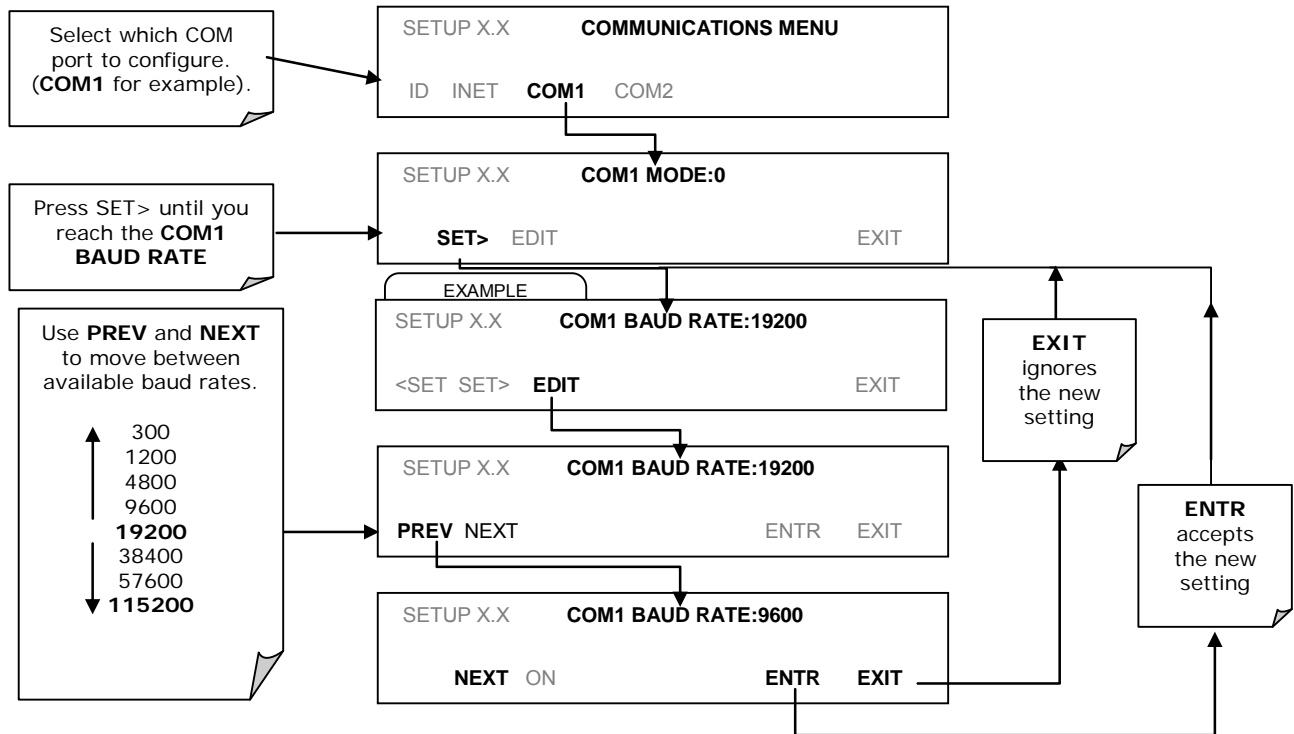
Figure 6-2: COMM – COMM Port Baud Rate

6.2.3. COMM PORT TESTING

The serial ports can be tested for correct connection and output in the **COMM** menu. This test sends a string of 256 'w' characters to the selected COM port. While the test is running, the red LED on the rear panel of the analyzer should flicker.

To initiate the test press, access the COMMUNICATIONS Menu (refer to Figure 5-13), then press:

SETUP X.X	**COMMUNICATIONS MENU**	
ID INET **COM1** COM2		EXIT

Select which COMM port to test.

SETUP X.X	**COM1 MODE:0**	
SET> EDIT		EXIT

SETUP X.X	COM1 BAUD RATE:19200	
<SET **SET>** EDIT		EXIT

SETUP X.X	**COM1 : TEST PORT**	
<SET **TEST**		EXIT

Test runs automatically

SETUP X.X	**TRANSMITTING TO COM1**	
<SET TEST		**EXIT**

EXIT returns to **COMM** menu
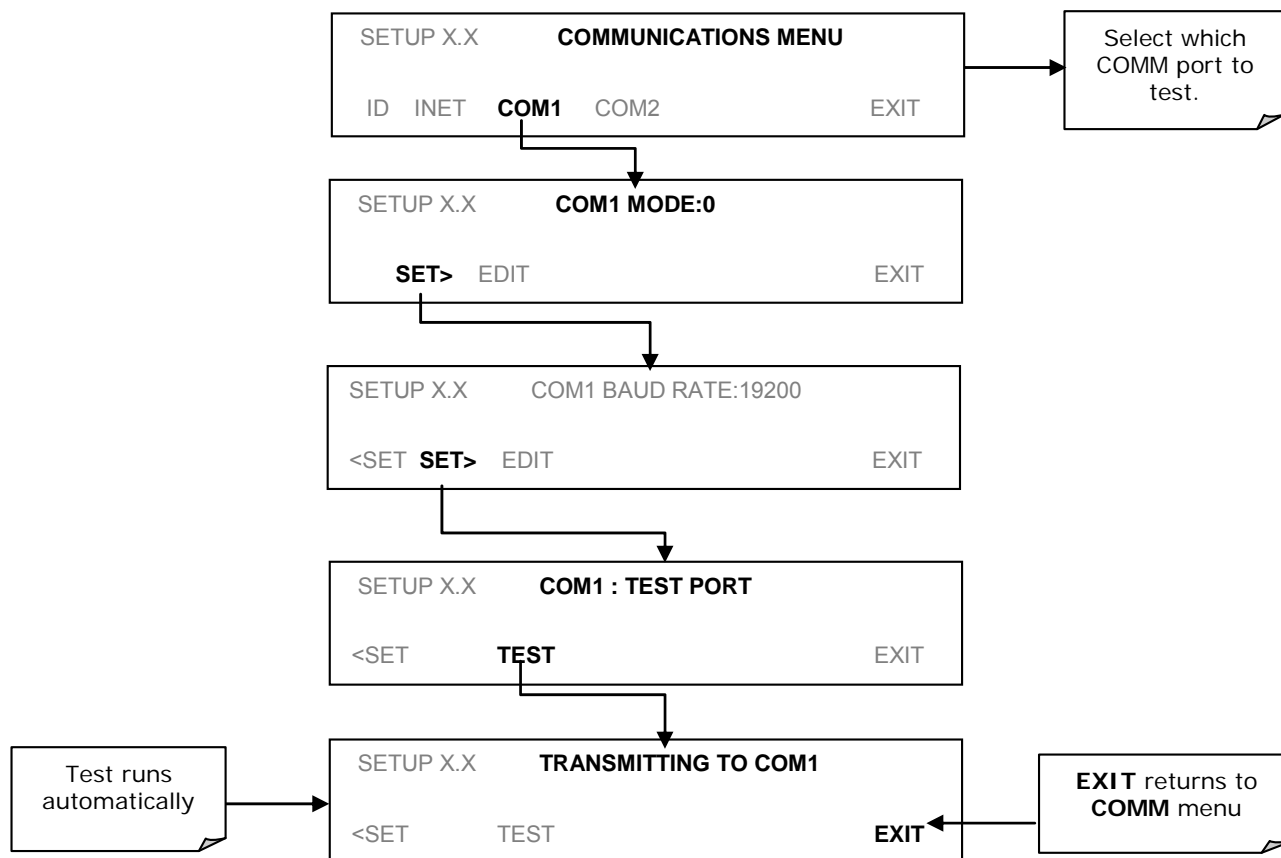
Figure 6-3: COMM – COM1 Test Port

6.3. RS-232

The **RS232** and **COM2** communications (COMM) ports operate on the RS-232 protocol (default configuration). Possible configurations for these two COMM ports are summarized as follows:

- **RS232** port can also be configured to operate in single or RS-232 Multidrop mode (Option 62); refer to Section 3.3.1.8.

- **COM2** port can be left in its default configuration for standard RS-232 operation including multidrop, or it can be reconfigured for half-duplex RS-485 operation (please contact the factory for this configuration).

Note that when the rear panel **COM2** port is in use, except for multidrop communication, the rear panel USB port cannot be used. (Alternatively, when the USB port is enabled, **COM2** port cannot be used except for multidrop)

A code-activated switch (CAS), can also be used on either port to connect typically between 2 and 16 send/receive instruments (host computer(s) printers, data loggers, analyzers, monitors, calibrators, etc.) into one communications hub. Contact Teledyne API Sales for more information on CAS systems.

To configure the analyzer's communication ports, use the SETUP>MORE>COMM menu. Refer to Section 5.7 for initial setup, and to Section 6.2 for additional configuration information.

6.4. RS-485 (OPTION)

The COM2 port of the instrument's rear panel is set up for RS-232 communication but can be reconfigured for RS-485 communication. Contact Technical Support. If this option was elected at the time of purchase, the rear panel was preconfigured at the factory.

6.5. ETHERNET

When using the Ethernet interface, the analyzer can be connected to any standard 10BaseT or 100BaseT Ethernet network via low-cost network hubs, switches or routers. The interface operates as a standard TCP/IP device on port 3000. This allows a remote computer to connect through the network to the analyzer using APICOM, terminal emulators or other programs.

The Ethernet cable connector on the rear panel has two LEDs indicating the Ethernet's current operating status.

Table 6-2: Ethernet Status Indicators

LED	FUNCTION
amber (link)	On when connection to the LAN is valid.
green (activity	Flickers during any activity on the LAN.

The analyzer is shipped with DHCP enabled by default. This allows the instrument to be connected to a network or router with a DHCP server. The instrument will automatically be assigned an IP address by the DHCP server (Section 6.5.2). This configuration is useful for quickly getting an instrument up and running on a network. However, for permanent Ethernet connections, a static IP address should be used. Section 6.5.1 below details how to configure the instrument with a static IP address.

6.5.1. CONFIGURING ETHERNET COMMUNICATION MANUALLY (STATIC IP ADDRESS)

1. Connect a cable from the analyzer's Ethernet port to a Local Area Network (LAN) or Internet port.

2. From the analyzer's front panel touchscreen, access the Communications Menu (SETUP>MORE>COMM as shown in Figure 5-13.

3. Follow the setup sequence as shown in Figure 6-4, and edit the Instrument and Gateway IP addresses and Subnet Mask to the desired settings.

4. From the computer, enter the same information through an application such as HyperTerminal.

Table 6-3 shows the default Ethernet configuration settings.

Table 6-3: LAN/Internet Default Configuration Properties

PROPERTY	DEFAULT STATE	DESCRIPTION
DHCP	ON	This displays whether the DHCP is turned ON or OFF. Press EDIT and toggle ON for automatic configuration after first consulting network administrator. (
INSTRUMENT IP ADDRESS		This string of four packets of 1 to 3 numbers each (e.g. 192.168.76.55.) is the address of the analyzer itself.
GATEWAY IP ADDRESS	0.0.0.0	Can only be edited when DHCP is set to OFF. A string of numbers very similar to the Instrument IP address (e.g. 192.168.76.1.) that is the address of the computer used by your LAN to access the Internet.
SUBNET MASK	0.0.0.0	Can only be edited when DHCP is set to OFF. Also a string of four packets of 1 to 3 numbers each (e.g. 255.255.252.0) that identifies the LAN to which the device is connected. All addressable devices and computers on a LAN must have the same subnet mask. Any transmissions sent to devices with different subnets are assumed to be outside of the LAN and are routed through the gateway computer onto the Internet.
TCP PORT[1]	3000	This number defines the terminal control port by which the instrument is addressed by terminal emulation software, such as Internet or Teledyne API's APICOM.
HOST NAME	T100	The name by which your analyzer will appear when addressed from other computers on the LAN or via the Internet. To change, see Section 6.5.2.1.
[1] Do not change the setting for this property unless instructed to by Teledyne API's Technical Support personnel.		

Internet Configuration Button Functions

BUTTON	FUNCTION
[0]	Location of cursor. Press to cycle through the range of numerals and available characters ("**0 – 9**" & " **.** ")
<CH CH>	Moves the cursor one character left or right.
DEL	Deletes a character at the cursor location.
ENTR	Accepts the new setting and returns to the previous menu.
EXIT	Ignores the new setting and returns to the previous menu.
Some buttons appear only when relevant.	

SETUP X.X   **COMMUNICATIONS MENU**

ID   **INET**   COM1   COM2   EXIT

SAMPLE   **ENTER SETUP PASS : 818**

        8   1   8   **ENTR** EXIT

DHCP: ON is default setting. Skip this step if it has been set to OFF.

SETUP X.X   **DHCP: ON**

    SET> **EDIT**   EXIT

SETUP X.X   **DHCP: OFF**

    SET> EDIT   EXIT

SETUP X.X   **INST IP: 000.000.000.000**

<SET SET> EDIT   EXIT

Cursor location is indicated by brackets

SETUP X.X   **INST IP: [0] 00.000.000**

<CH CH>   DEL **[0]**   **ENTR EXIT**

SETUP X.X   **GATEWAY IP: 000.000.000.000**

<SET   SET> EDIT   EXIT

SETUP X.X   **GATEWAY IP: [0] 00.000.000**

<CH CH>   DEL **[?]**   **ENTR EXIT**

SETUP X.X   **SUBNET MASK:255.255.255.0**

<SET   SET> EDIT   EXIT

SETUP X.X   **SUBNET MASK:[2]55.255.255.0**

<CH CH>   DEL **[?]**   **ENTR EXIT**

SETUP X.X   **TCP PORT 3000**

    <SET   EDIT   EXIT

The PORT number must remain at **3000**. Do not change this setting unless instructed to by Teledyne Instruments Customer Service personnel.

Pressing **EXIT** from any of the above display menus causes the Ethernet option to reinitialize its internal interface firmware

SETUP X.X   **INITIALIZING INET   0%**
            ...
        INITIALIZING INET 100%

SETUP X.X   **INITIALIZATI0N SUCCEEDED**

SETUP X.X   **INITIALIZATION FAILED**

Contact your IT Network Administrator

SETUP X.X   **COMMUNICATIONS MENU**

ID   INET   COM1   COM2   EXIT

Figure 6-4: COMM – LAN / Internet Manual Configuration

6.5.2. CONFIGURING ETHERNET COMMUNICATION USING DYNAMIC HOST CONFIGURATION PROTOCOL (DHCP)

1. Consult with your network administrator to affirm that your network server is running DHCP.

2. Access the Communications Menu as shown in Figure 5-13.

3. Follow the setup sequence as shown in Figure 6-5.
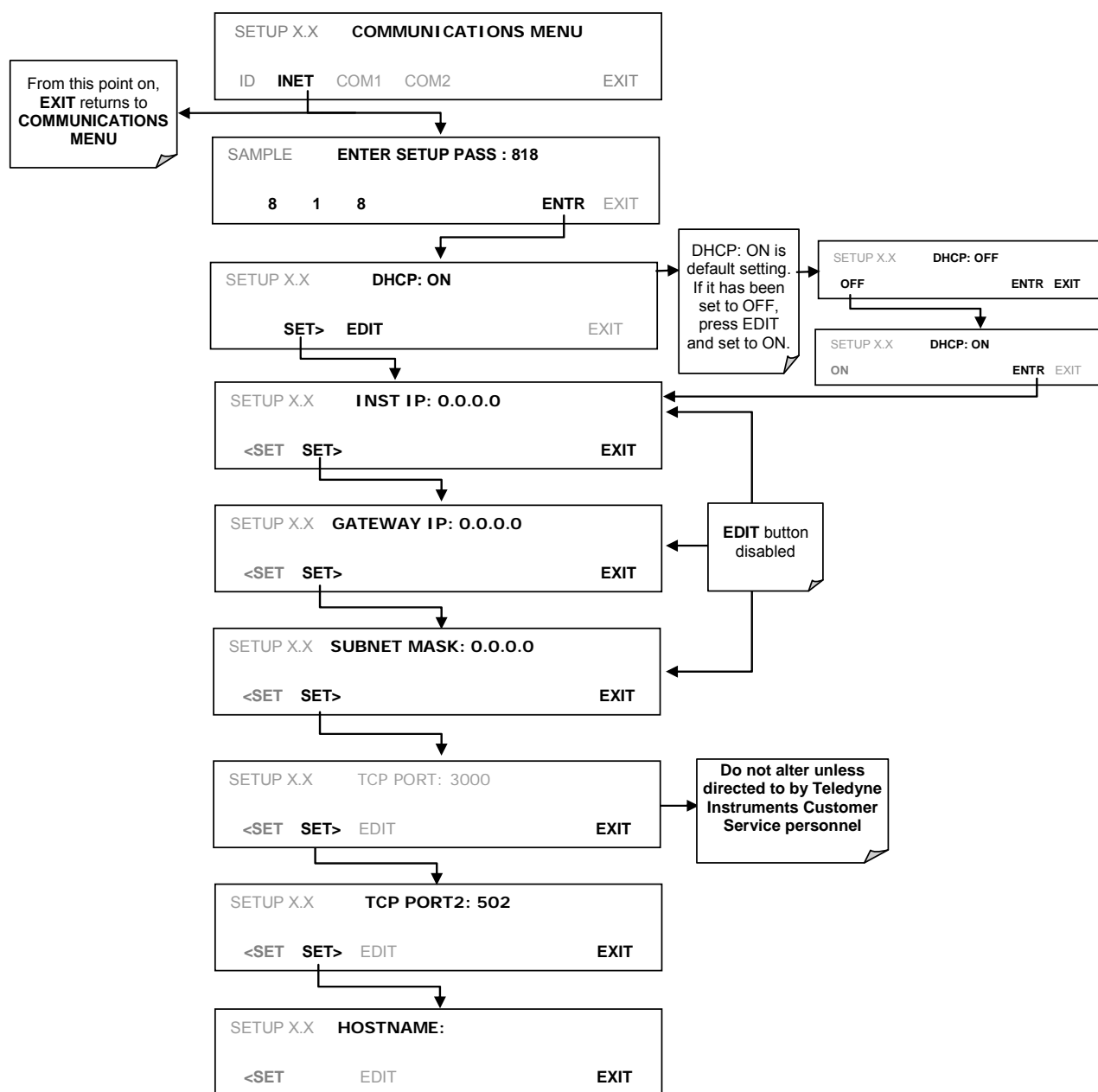
Figure 6-5: COMM – LAN / Internet Automatic Configuration

6.5.2.1. **CHANGING THE ANALYZER'S HOSTNAME**

The **HOSTNAME** is the name by which the analyzer appears on your network. The default name for all Teledyne API's T100 analyzers is **T100**. To change this name (particularly if you have more than one T100 analyzer on your network), access the COMMUNICATIONS Menu (refer to Figure 5-13), then press:
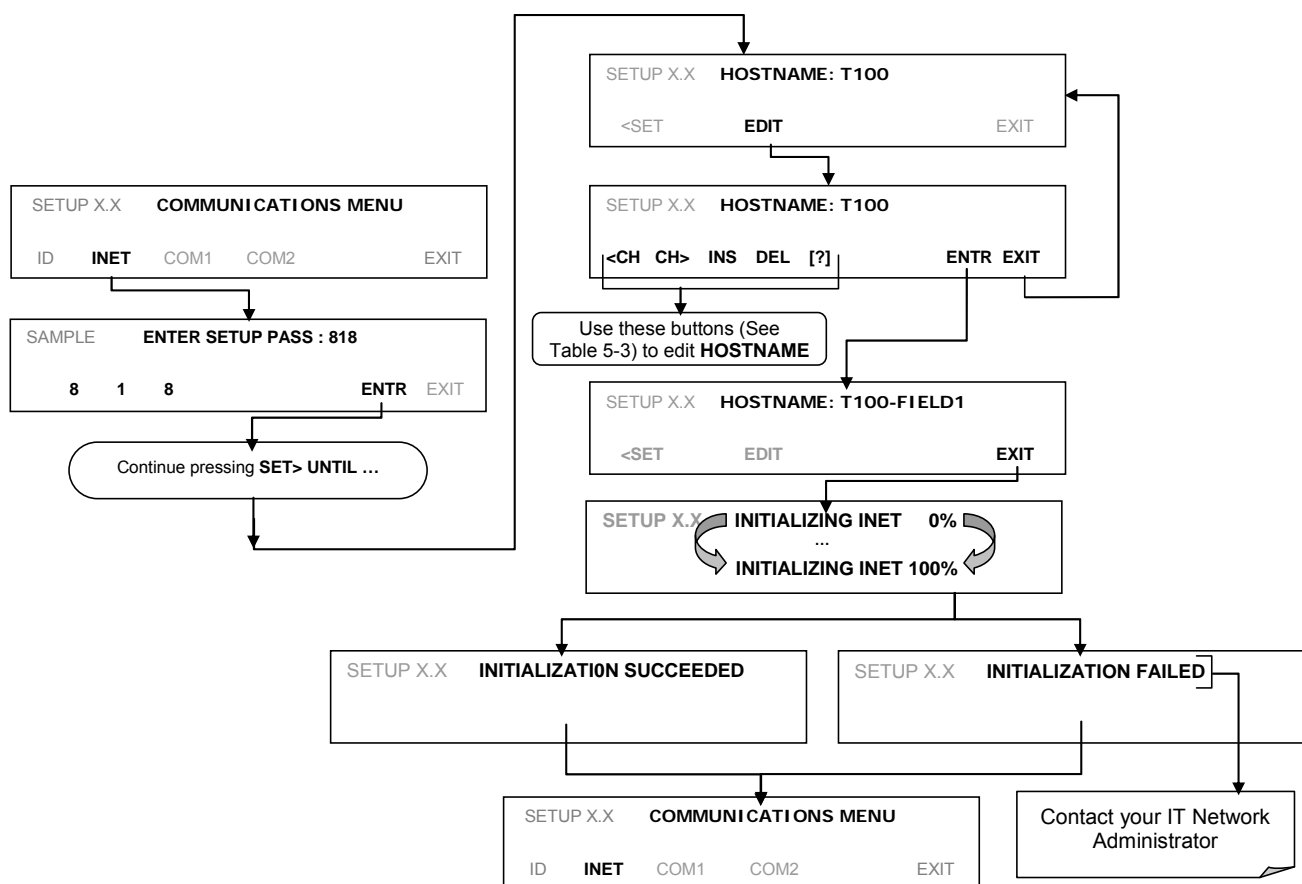
Figure 6-6: COMM – Change Hostname

Table 6-4: Hostname Editing Button Functions

Button	Function
<CH	Moves the cursor one character to the left.
CH>	Moves the cursor one character to the right.
INS	Inserts a character before the cursor location.
DEL	Deletes a character at the cursor location.
[?]	Press this button to cycle through the range of numerals and characters available for insertion.: 0-9, A-Z, space ' ~ ! © # $ % ^ & * ( ) - _ = +[ ] { } < >\	; : , . / ?
ENTR	Accepts the new setting and returns to the previous menu.
EXIT	Ignores the new setting and returns to the previous menu.
Buttons only appear when applicable.	

6.5.3. USB PORT FOR REMOTE ACCESS

The analyzer can be operated through a personal computer by downloading the TAPI USB driver and directly connecting their respective USB ports.

1. Install the Teledyne T-Series USB driver on your computer, downloadable from the Teledyne API website under Help Center>Software Downloads (www.teledyne-api.com/software).

2. Run the installer file: "TAPIVCPInstaller.exe"
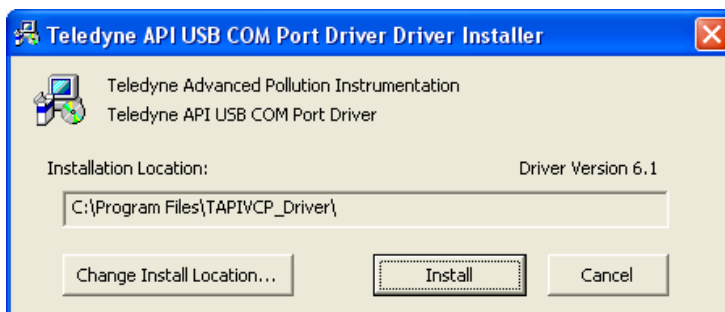
3. Connect the USB cable between the USB ports on your personal computer and your analyzer. The USB cable should be a Type A – Type B cable, commonly used as a USB printer cable.

4. Determine the Windows XP Com Port number that was automatically assigned to the USB connection. (Start → Control Panel → System → Hardware → Device Manager). This is the com port that should be set in the communications software, such as APIcom or Hyperterminal.
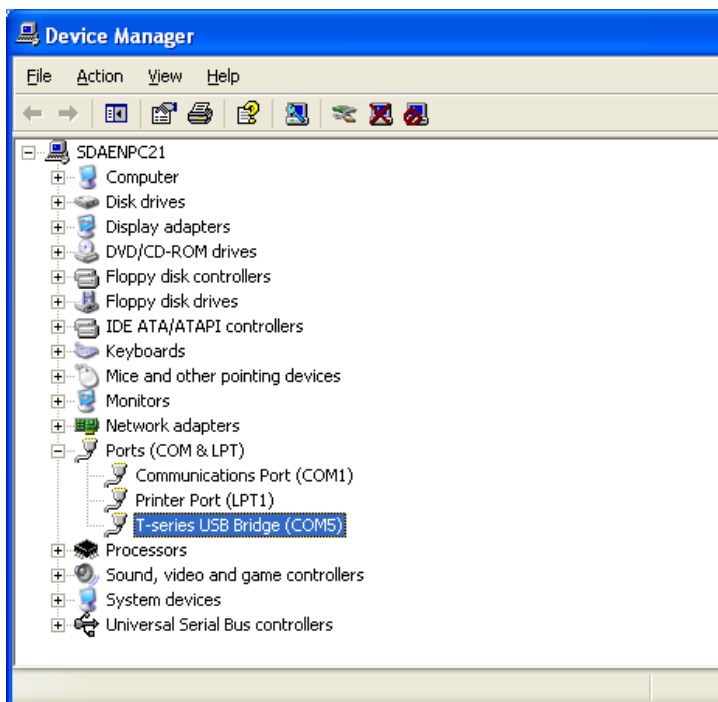
Refer to the Quick Start (*Direct Cable Connection*) section of the Teledyne APIcom Manual, PN 07463.

5. In the instrument's SETUP>MORE>COMM>COM2 menu, make the following settings:

Baud Rate: 115200			
COM2 Mode Settings:			
Quiet Mode	ON	SECURITY MODE	OFF
Computer Mode	ON	MULTIDROP MODE	OFF
MODBUS RTU	OFF	ENABLE MODEM	OFF
MODBUS ASCII	OFF	ERROR CHECKING	ON
E,8,1 MODE	OFF	XON/XOFF HANDSHAKE	OFF
E,7,1 MODE	OFF	HARDWARE HANDSHAKE	OFF
RS-485 MODE	OFF	HARDWARE FIFO	ON
		COMMAND PROMPT	OFF

6. Next, configure your communications software, such as APIcom. Use the COM port determined in Step 4 and the baud rate set in Step 5. The figures below show how these parameters would be configured in the Instrument Properties window in APIcom when configuring a new instrument. See the APIcom manual (PN 07463) for more details.
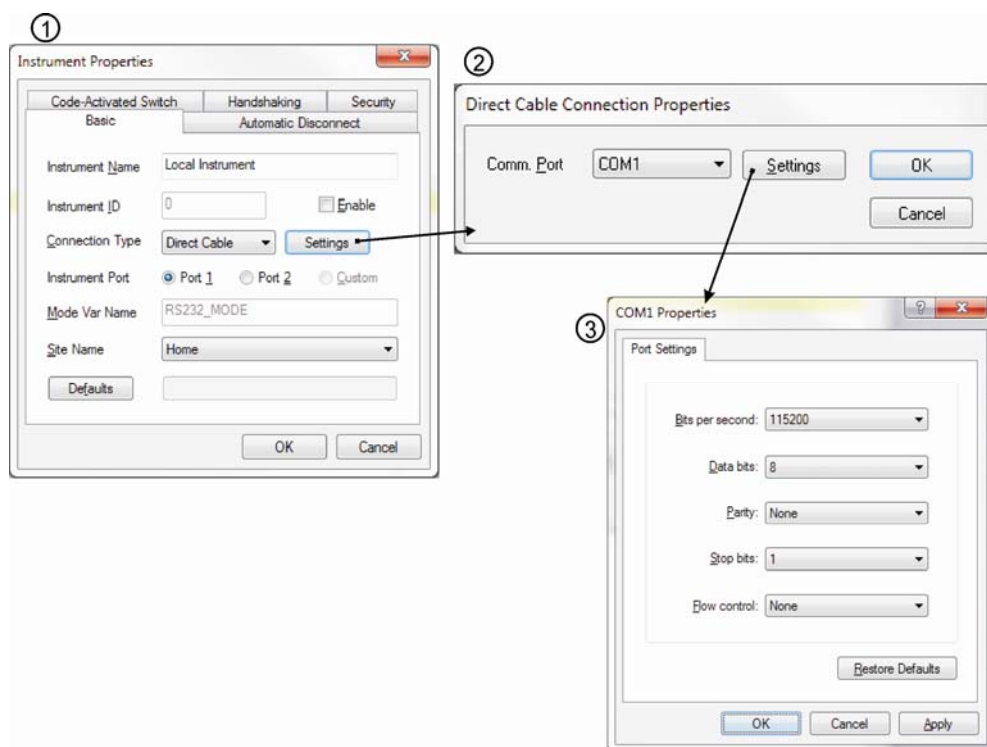
Note	• **USB configuration requires that the baud rates of the instrument and the PC match; check the PC baud rate and change if needed.**
	• **Using the USB port disallows use of the rear panel COM2 port except for multidrop communication.**

6.6. COMMUNICATIONS PROTOCOLS

6.6.1. MODBUS

The following set of instructions assumes that the user is familiar with MODBUS communications, and provides minimal information to get started. For additional instruction, please refer to the Teledyne API MODBUS manual, PN 06276. Also refer to www.modbus.org for MODBUS communication protocols.

Minimum Requirements

- Instrument firmware with MODBUS capabilities installed.
- MODBUS-compatible software (TAPI uses MODBUS Poll for testing; see www.modbustools.com)
- Personal computer
- Communications cable (Ethernet or USB or RS232)
- Possibly a null modem adapter or cable

MODBUS Setup:	
Set Com Mode parameters Comm	Ethernet: Using the front panel menu, go to SETUP – MORE – COMM – INET; scroll through the INET submenu until you reach TCP PORT 2 (the standard setting is 502), then continue to TCP PORT 2 MODBUS TCP/IP; press EDIT and toggle the menu button to change the setting to ON, then press ENTR. (Change Machine ID if needed: see "Slave ID"). USB/RS232: Using the front panel menu, go to SETUP – MORE – COMM – COM2 – EDIT; scroll through the COM2 EDIT submenu until the display shows COM2 MODBUS RTU: OFF (press OFF to change the setting to ON. Scroll NEXT to COM2 MODBUS ASCII and ensure it is set to OFF. Press ENTR to keep the new settings. (If RTU is not available with your communications equipment, set the COM2 MODBUS ASCII setting to ON and ensure that COM2 MODBUS RTU is set to OFF. Press ENTR to keep the new settings).
Slave ID	A MODBUS slave ID must be set for each instrument. Valid slave ID's are in the range of 1 to 247. If your analyzer is connected to a serial network (i.e., RS-485), a unique Slave ID must be assigned to each instrument. To set the slave ID for the instrument, go to SETUP – MORE – COMM – ID. The default MACHINE ID is the same as the model number. Toggle the menu buttons to change the ID.
Reboot analyzer	For the settings to take effect, power down the analyzer, wait 5 seconds, and power up the analyzer.
Make appropriate cable connections	Connect your analyzer either: • via its Ethernet or USB port to a PC (this may require a USB-to-RS232 adapter for your PC; if so, also install the software driver from the CD supplied with the adapter, and reboot the computer if required), or • via its COM2 port to a null modem (this may require a null modem adapter or cable).
Specify MODBUS software settings (examples used here are for MODBUS Poll software)	1. Click Setup / [Read / Write Definition] /. 　a. In the Read/Write Definition window (see example that follows) select a **Function** (what you wish to read from the analyzer). 　b. Input **Quantity** (based on your firmware's register map). 　c. In the View section of the Read/Write Definition window select a **Display** (typically Float Inverse). 　d. Click **OK**. 2. Next, click Connection/Connect. 　a. In the Connection Setup window (see example that follows), select the options based on your computer. 　b. Press **OK**.
Read the Modbus Poll Register	Use the Register Map to find the test parameter names for the values displayed (see example that follows If desired, assign an alias for each.

Example Read/Write Definition window:

Example Connection Setup window:

Example MODBUS Poll window:

6.6.2. HESSEN

The Hessen protocol is a Multidrop protocol, in which several remote instruments are connected via a common communications channel to a host computer. The remote instruments are regarded as slaves of the host computer. The remote instruments are unaware that they are connected to a Multidrop bus and never initiate Hessen protocol messages. They only respond to commands from the host computer and only when they receive a command containing their own unique ID number.

The Hessen protocol is designed to accomplish two things: to obtain the status of remote instruments, including the concentrations of all the gases measured; and to place remote instruments into zero or span calibration or measure mode. API's implementation supports both of these principal features.

The Hessen protocol is not well defined; therefore while API's application is completely compatible with the protocol itself, it may be different from implementations by other companies.

The following subsections describe the basics for setting up your instrument to operate over a Hessen Protocol network. For more detailed information as well as a list of host computer commands and examples of command and response message syntax, download the *Manual Addendum for Hessen Protocol* from the Teledyne API's website: http://www.teledyne-api.com/manuals/index.asp.

6.6.2.1. HESSEN COMM PORT CONFIGURATION

Hessen protocol requires the communication parameters of the T100's COMM ports to be set differently than the standard configuration as shown in the table below.

Table 6-5: RS-232 Communication Parameters for Hessen Protocol

Parameter	Standard	Hessen
Data Bits	8	7
Stop Bits	1	2
Parity	None	Even
Duplex	Full	Half

To change the rest of the COMM port parameters and modes, refer to Section 6.

To change the baud rate of the T100's COMM ports, refer to Section 6.2.2.

IMPORTANT

IMPACT ON READINGS OR DATA

Ensure that the communication parameters of the host computer are also properly set.

Note

The instrument software has a 200 ms latency before it responds to commands issued by the host computer. This latency should present no problems, but you should be aware of it and not issue commands to the instrument too quickly.

6.6.2.2. **ACTIVATING HESSEN PROTOCOL**

The first step in configuring the T100 to operate over a Hessen protocol network is to activate the Hessen mode for COMM ports and configure the communication parameters for the port(s) appropriately. Access the COMMUNICATIONS Menu (refer to Figure 5-13), then press:
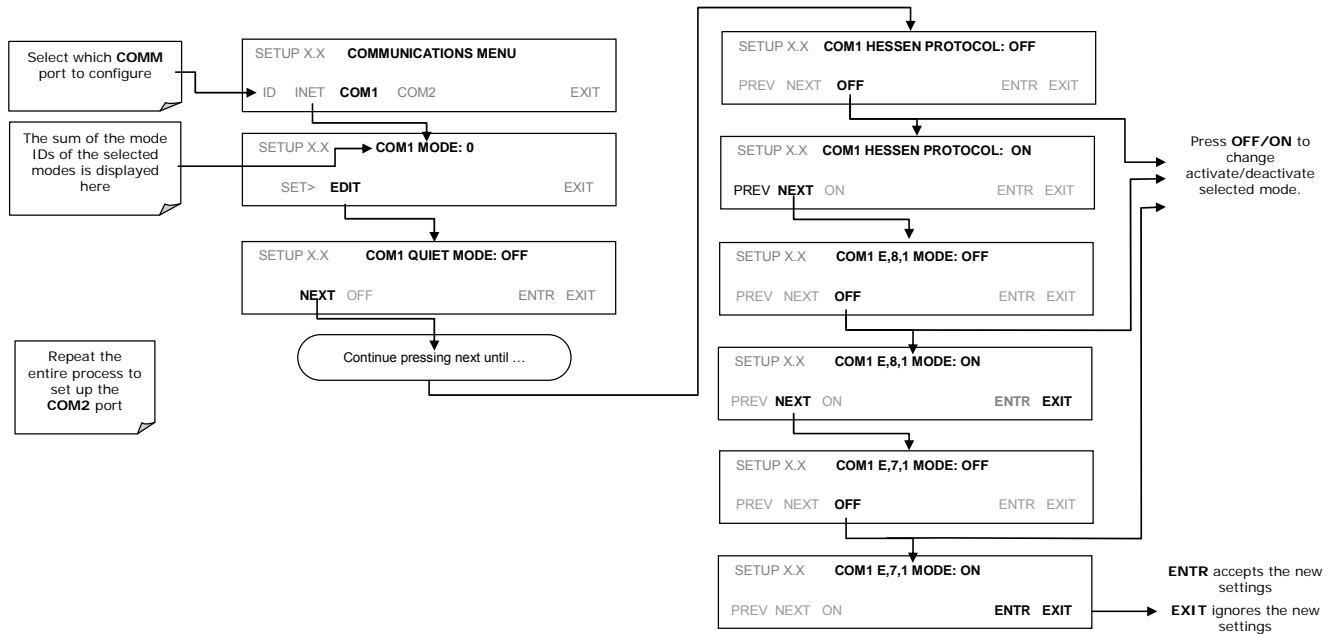
Figure 6-7: COMM – Activating Hessen Protocol

6.6.2.3. **SELECTING A HESSEN PROTOCOL TYPE**

Currently there are two version of Hessen Protocol in use. The original implementation, referred to as **TYPE 1**, and a more recently released version, **TYPE 2** that has more flexibility when operating with instruments that can measure more than one type of gas. For more specific information about the difference between **TYPE 1** and **TYPE 2** download the *Manual Addendum for Hessen Protocol* from Teledyne API's web site: http://www.teledyne-api.com/manuals/index.asp.

To select a Hessen Protocol Type, access the COMMUNICATIONS Menu (refer to Figure 5-13), then press:
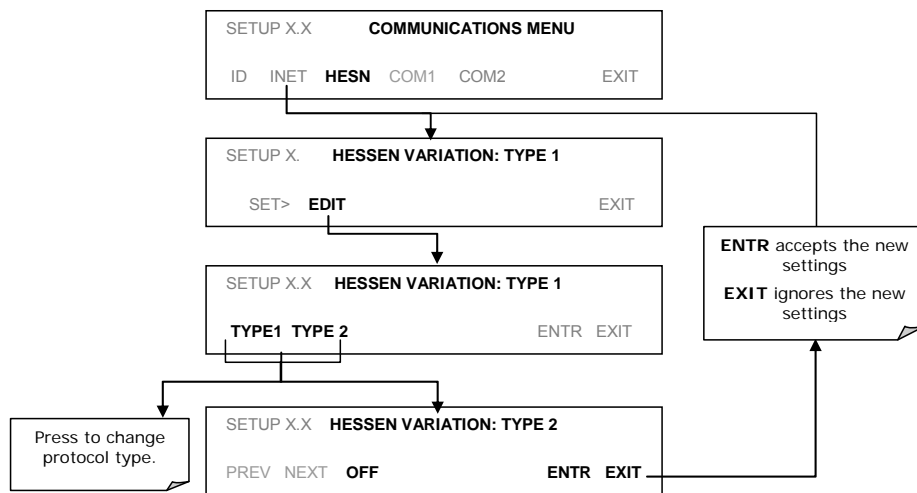
Figure 6-8: COMM – Select Hessen Protocol Type

Note   **While Hessen Protocol Mode can be activated independently for RS-232 and COM2, the TYPE selection affects both Ports.**

6.6.2.4. **SETTING THE HESSEN PROTOCOL RESPONSE MODE**

Teledyne API's implementation of Hessen Protocol allows the user to choose one of several different modes of response for the analyzer.

Table 6-6: T100 Hessen Protocol Response Modes

MODE ID	MODE DESCRIPTION
CMD	This is the Default Setting. Reponses from the instrument are encoded as the traditional command format. Style and format of responses depend on exact coding of the initiating command.
BCC	Responses from the instrument are always delimited with <STX> (at the beginning of the response, <ETX> (at the end of the response followed by a 2 digit Block Check Code (checksum), regardless of the command encoding.
TEXT	Responses from the instrument are always delimited with <CR> at the beginning and the end of the string, regardless of the command encoding.

To Select a Hessen response mode, access the COMMUNICATIONS Menu (refer to Figure 5-13), then press:
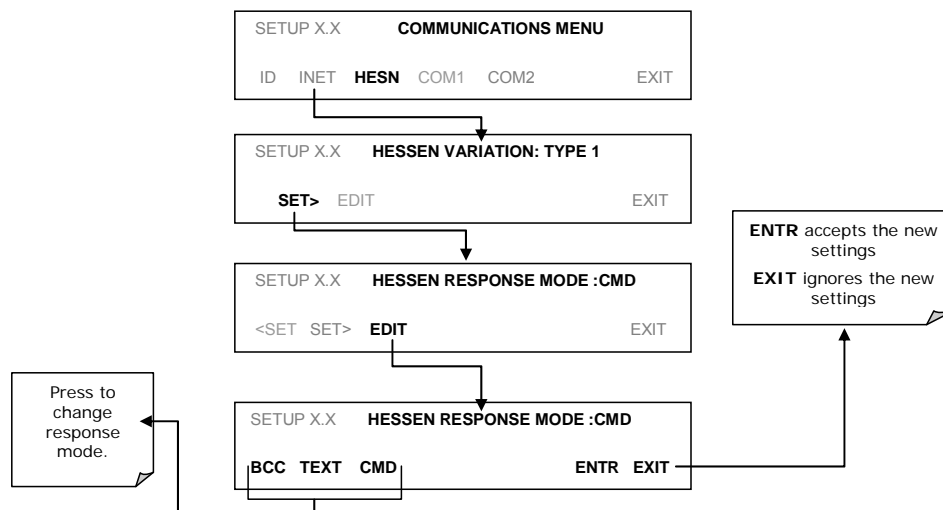
Figure 6-9: COMM – Select Hessen Protocol Response Mode

6.6.2.5. **HESSEN PROTOCOL GAS ID**

The T100 analyzer is a single gas instrument that measures SO_2. As such, its default gas ID has already been set to **110.**   There is no need to change this setting.

6.6.2.6. **SETTING HESSEN PROTOCOL STATUS FLAGS**

Teledyne API's implementation of Hessen protocols includes a set of status bits that the instrument includes in responses to inform the host computer of its condition. Each bit can be assigned to one operational and warning message flag. The default settings for these bit/flags are listed in Table 6-7:

Table 6-7: Default Hessen Status Bit Assignments

STATUS FLAG NAME		DEFAULT BIT ASSIGNMENT
WARNING FLAGS		
SAMPLE FLOW WARNING		0001
PMT DET WARNING		0002
UV LAMP WARNING		0002
HVPS WARNING		0004
DARK CAL WARNING		0008
RCELL TEMP WARNING		0010
IZS TEMP WARNING		0020
PMT TEMP WARNING		0040
INVALID CONC		0080
OPERATIONAL FLAGS		
In Manual Calibration Mode		0200
In Zero Calibration Mode		0400
In Span Calibration Mode		0800
UNITS OF MEASURE FLAGS		
UGM		0000
MGM		2000
PPB		4000
PPM		6000
SPARE/UNUSED BITS		100. 8000
UNASSIGNED FLAGS		
Box Temp Warning	MP Calibration	
Sample Press Warning	Analog Cal Warning	
System Reset	Cannot Dyn Zero	
Rear Board Not Detected	Cannot Dyn Span	
Relay Board Warning	Instrument Off	

IMPORTANT

IMPACT ON READINGS OR DATA

It is possible to assign more than one flag to the same Hessen status bit. This allows the grouping of similar flags, such as all temperature warnings, under the same status bit. Be careful not to assign conflicting flags to the same bit as each status bit will be triggered if any of the assigned flags are active.

To assign or reset the status flag bit assignments, access the COMMUNICATIONS Menu (refer to Figure 5-13), then press:
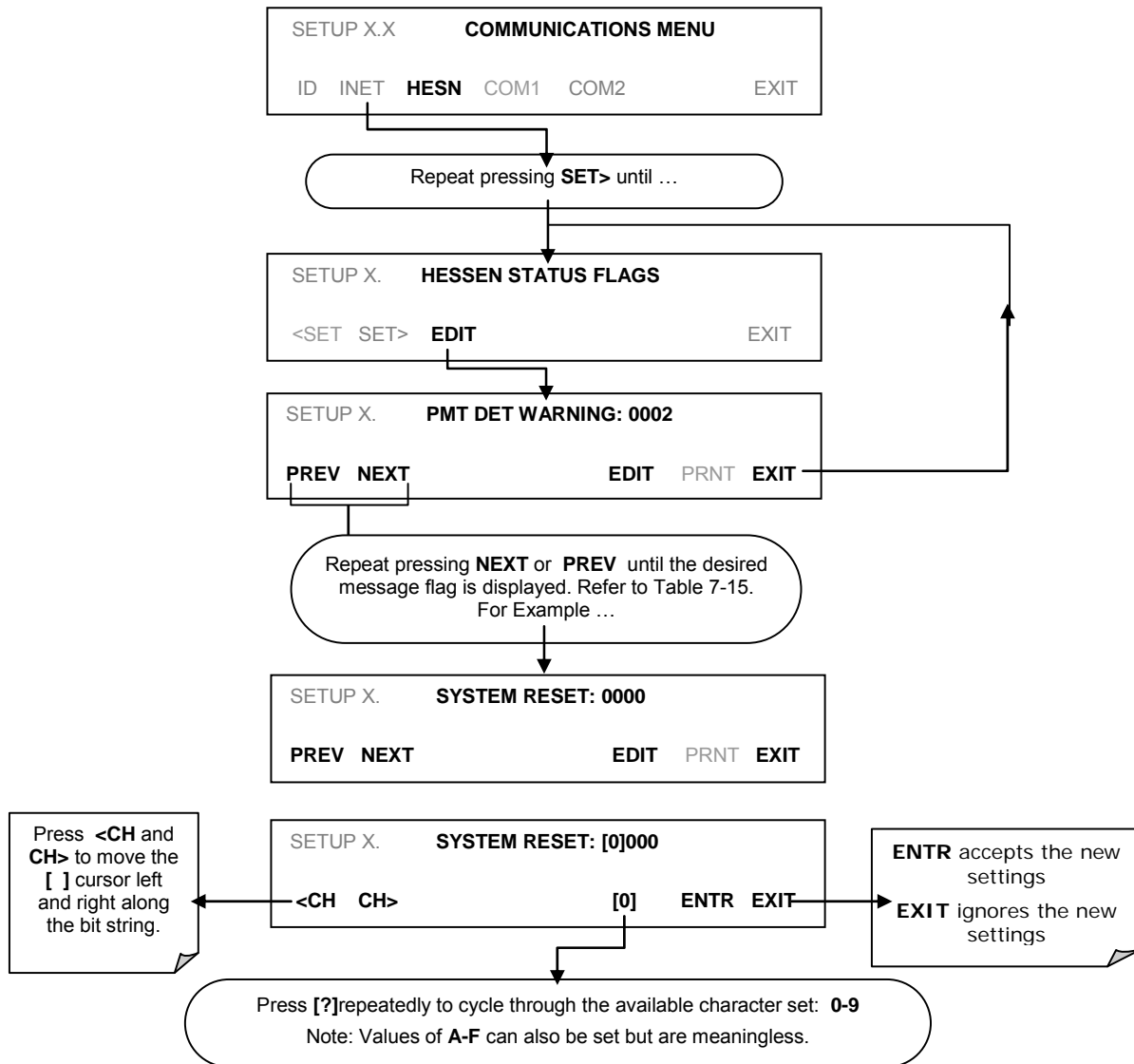
Figure 6-10:   COMM – Status Flag Bit Assignment

6.6.2.7. **INSTRUMENT ID**

Each instrument on a Hessen Protocol network must have a unique identifier (ID number). Refer to Section 5.7.1 for information and to customize the ID of each.

7. DATA ACQUISITION SYSTEM (DAS) AND APICOM

The T100 analyzer contains a flexible and powerful, internal data acquisition system (DAS) that enables the analyzer to store concentration and calibration data as well as a host of diagnostic parameters. The DAS of the T100 can store up to about one million data points, which can, depending on individual configurations, cover days, weeks or months of valuable measurements. The data are stored in non-volatile memory and are retained even when the instrument is powered off. Data are stored in plain text format for easy retrieval and use in common data analysis programs (such as spreadsheet-type programs).

The DAS is designed to be flexible, users have full control over the type, length and reporting time of the data. The DAS permits users to access stored data through the instrument's front panel or its communication ports. Using APICOM, data can even be retrieved automatically to a remote computer for further processing.

The principal use of the DAS is logging data for trend analysis and predictive diagnostics, which can assist in identifying possible problems before they affect the functionality of the analyzer. The secondary use is for data analysis, documentation and archival in electronic format.

To support the DAS functionality, Teledyne API offers APICOM, a program that provides a visual interface for remote or local setup, configuration and data retrieval of the DAS. The APICOM manual, which is included with the program, contains a more detailed description of the DAS structure and configuration, which is briefly described in this section.

The T100 is configured with a basic DAS configuration, which is enabled by default. New data channels are also enabled by default but each channel may be turned off for later or occasional use. Note that DAS operation is suspended while its configuration is edited through the front panel. To prevent such data loss, it is recommended to use the APICOM graphical user interface for DAS changes.

The green SAMPLE LED on the instrument front panel, which indicates the analyzer status, also indicates certain aspects of the DAS status, as described in Table 7-1

Table 7-1: Front Panel LED Status Indicators for DAS

LED STATE	DAS STATUS
Off	System is in calibration mode. Data logging can be enabled or disabled for this mode. Calibration data are typically stored at the end of calibration periods, concentration data are typically not sampled, diagnostic data should be collected.
Blinking	Instrument is in hold-off mode, a short period after the system exits calibrations. DAS channels can be enabled or disabled for this period. Concentration data are typically disabled whereas diagnostic should be collected.
On	Sampling normally.

Note   **The DAS can be disabled only by disabling or deleting its individual data channels.**

7.1. DAS STRUCTURE

The DAS is designed around the feature of a "record". A record is a single data point of one parameter, stored in one (or more) data channels and generated by one of several triggering event. The entire DAS configuration is stored in a script, which can be edited from the front panel or downloaded, edited and uploaded to the instrument in form of a string of plain-text lines through the communication ports.

DAS data are defined by the PARAMETER type and are stored through different triggering EVENTS in data CHANNELS, which relate triggering events to data parameters and define certain operational functions related to the recording and reporting of the data.

7.1.1. DAS CHANNELS

The key to the flexibility of the DAS is its ability to store a large number of combinations of triggering events and data parameters in the form of data channels. Users may create up to 20 data channels and each channel can contain one or more parameters. For each channel one triggering event is selected and up to 50 data parameters, which can be the same or different between channels. Each data channel has several properties that define the structure of the channel and allow the user to make operational decisions regarding the channel (refer to Table 7-2).

Table 7-2: DAS Data Channel Properties

Property	Description	Default	Setting Range
NAME	The name of the data channel.	"NONE"	Up to 6 letters and digits (more with APICOM, but only the first six are displayed on the front panel).
TRIGGERING EVENT	The event that triggers the data channel to measure and store its data parameters. Refer to APPENDIX A-5 for a list of available triggering events.	ATIMER	Any allowed event.
NUMBER AND LIST OF PARAMETERS	A User-configurable list of data types to be recorded in any given channel. Refer to APPENDIX A-5 for a list of available parameters	1 - PMTDET	Any available concentration, temperature, pneumatic or diagnostic parameter.
REPORT PERIOD	The amount of time between each channel data point.	000:01:00	000:00:01 to 366:23:59 (Days:Hours:Minutes)
NUMBER OF RECORDS	The number of reports that will be stored in the data file. Once the specified limit has been exceeded, the oldest data are over-written to make space for new data.	100	1 to 1 million, limited by available storage space.
RS-232 REPORT	Enables the analyzer to automatically report channel values to the RS-232 ports.	OFF	OFF or ON
CHANNEL ENABLED	Enables or disables the channel. Provides a convenient means to temporarily disable a data channel.	ON	OFF or ON
CAL HOLD OFF	Disables sampling of data parameters while instrument is in calibration mode. Note that - when enabled here - there is also a length of the DAS HOLD OFF after calibration mode, which is set in the VARS menu (refer to Section 7.2.11).	OFF	OFF or ON

7.1.2. DAS PARAMETERS

Data parameters are types of data that may be measured and stored by the DAS. For each Teledyne API's analyzer model, the list of available data parameters is different, fully defined and not customizable. Appendix A-5 lists firmware specific data parameters for the T100. The most common parameters are concentrations of the measured gas (SO_2), temperatures of heated zones (converter, sample chamber, box temperature…), pressures and flows of the pneumatic subsystem and other diagnostic measurements as well as calibration data (slope and offset) for each gas.

Most data parameters have associated measurement units, such as mV, ppb, cm³/min, etc., although some parameters have no units. The only units that can be changed are those of the concentration readings according to the **SETUP-RANGE** settings. Note that the DAS does not keep track of the unit of each concentration value and DAS data files may contain concentrations in multiple units if the unit was changed during data acquisition.

Each data parameter has user-configurable functions that define how the data are recorded (refer to Table 7-3).

Table 7-3: DAS Data Parameter Functions

FUNCTION	EFFECT
PARAMETER	Instrument-specific parameter name.
SAMPLE MODE	**INST**: Records instantaneous reading. **AVG**: Records average reading during reporting interval. **MIN**: Records minimum (instantaneous) reading during reporting interval. **MAX**: Records maximum (instantaneous) reading during reporting interval.
PRECISION	Decimal precision of parameter value (0-4).
STORE NUM. SAMPLES	**OFF**: stores only the average (default). **ON**: stores the average and the number of samples in each average for a parameter. This property is only useful when the **AVG** sample mode is used. Note that the number of samples is the same for all parameters in one channel and needs to be specified only for one of the parameters in that channel.

Users can specify up to 50 parameters per data channel (the T100 provides about 30 parameters). However, the number of parameters and channels is ultimately limited by available memory.

7.1.3. DAS TRIGGERING EVENTS

Triggering events define when and how the DAS records a measurement of any given data channel. Triggering events are firmware-specific and are listed in Appendix A-5. The most common triggering events are:

- **ATIMER**: Sampling at regular intervals specified by an automatic timer. Most trending information is usually stored at such regular intervals, which can be instantaneous or averaged.

- **EXITZR**, **EXITSP**, **SLPCHG** (exit zero, exit span, slope change): Sampling at the end of (irregularly occurring) calibrations or when the response slope changes. These triggering events create instantaneous data points, e.g., for the new slope and offset (concentration response) values at the end of a calibration. Zero and slope values are valuable to monitor response drift and to document when the instrument was calibrated.

- **WARNINGS**: Some data may be useful when stored if one of several warning messages appears. This is helpful for trouble-shooting by monitoring when a particular warning occurred.

7.2. DEFAULT DAS CHANNELS

A set of default Data Channels has been included in the analyzer's software for logging SO$_2$ concentration and certain predictive diagnostic data. These default channels include but are not limited to:

CONC: Samples SO$_2$ concentration at one minute intervals and stores an average every five minutes with a time and date stamp. Readings during calibration and calibration hold off are not included in the data. By default, the last 4032 hourly averages are stored.

PNUMTC: Collects sample flow and sample pressure data at five minute intervals and stores an average once a day with a time and date stamp. This data is useful for monitoring the condition of the pump and critical flow orifice (sample flow) and the

sample filter (clogging indicated by a drop in sample pressure) over time to predict when maintenance will be required. The last 360 daily averages (about 1 year) are stored.

CALDAT: Logs new slope and offset every time a zero or span calibration is performed. This Data Channel also records the instrument reading just prior to performing a calibration. *Note:* this Data Channel collects data based on an event (a calibration) rather than a timer. This Data Channel will store data from the last 200 calibrations. This does not represent any specific length of time since it is dependent on how often calibrations are performed. As with all Data Channels, a time and date stamp is recorded for every data point logged.

DETAIL: Samples fourteen different parameters related to the operating status of the analyzers optical sensors and PMT. For each parameter:

- A value is logged once every minute;

- An average of the last 60 readings is calculated once every.

- The last 480 averages are stored (20 days).

This channel is useful for diagnosing problems that cause the instruments measurements to drift slowly over time

FAST: Almost identical to **DETAIL** except that for each parameter:

- Samples are taken once per minute and reported once per minute, in effect causing the instrument to record an instantaneous reading of each parameter every minute.

- The last 360 readings for each parameter are recorded/reported.

This channel is useful for diagnosing transients; spikes and noise problems.

These default Data Channels can be used as they are, or they can be customized to fit a specific application. They can also be deleted to make room for custom user-programmed Data Channels. This can be done via the instrument's front panel or downloaded via the analyzer's COM ports using a program such as APICOM (Section 7.3) or other terminal emulation program.

IMPORTANT

IMPACT ON READINGS OR DATA

Sending a DAS configuration to the analyzer through its COM ports will replace the existing configuration and will delete all stored data. Back up any existing data and the DAS configuration before uploading new settings

---

The Channel Properties, Triggering Events and Data Parameters/Functions for these default channels are:

PARAMETER: **PMTDET**
MODE: **AVG**
PRECISION: **4**
STORE NUM SAMPLES **OFF**

PARAMETER: **UVDET**
MODE: **AVG**
PRECISION: **4**
STORE NUM SAMPLES **OFF**

PARAMETER: **LAMPR**
MODE: **AVG**
PRECISION: **4**
STORE NUM SAMPLES **OFF**

PARAMETER: **DRKPMT**
MODE: **AVG**
PRECISION: **4**
STORE NUM SAMPLES **OFF**

PARAMETER: **DARKUV**
MODE: **AVG**
PRECISION: **4**
STORE NUM SAMPLES **OFF**

PARAMETER: **CONC1**
MODE: **AVG**
PRECISION: **3**
STORE NUM SAMPLES **OFF**

PARAMETER: **STABIL**
MODE: **AVG**
PRECISION: **4**
STORE NUM SAMPLES **OFF**

PARAMETER: **STRLGT**
MODE: **AVG**
PRECISION: **4**
STORE NUM SAMPLES **OFF**

PARAMETER: **RCTEMP**
MODE: **AVG**
PRECISION: **2**
STORE NUM SAMPLES **OFF**

PARAMETER: **SMPPRS**
MODE: **AVG**
PRECISION: **4**
STORE NUM SAMPLES **OFF**

PARAMETER: **BOXTEMP**
MODE: **AVG**
PRECISION: **4**
STORE NUM SAMPLES **OFF**

PARAMETER: **HVPS**
MODE: **AVG**
PRECISION: **4**
STORE NUM SAMPLES **OFF**

PARAMETER: **REFGND**
MODE: **AVG**
PRECISION: **4**
STORE NUM SAMPLES **OFF**

PARAMETER: **REF4096**
MODE: **AVG**
PRECISION: **4**
STORE NUM SAMPLES **OFF**

LIST OF CHANNELS

NAME: **CONC**
EVENT: **ATIMER**
PARAMETERS: **2**
STARTING DATE: 01-JAN-07
SAMPLE PERIOD: 000:00:01
REPORT PERIOD: **000:00:05**
NO. OF RECORDS: **4032**
RS-232 REPORT: **ON**
COMPACT REPORT: **OFF**
CHANNEL ENABLED: **ON**

NAME: **PNUMTC**
EVENT: **ATIMER**
PARAMETERS: **2**
STARTING DATE: 01-JAN-07
SAMPLE PERIOD: 000:00:05
REPORT PERIOD: **001:00:00**
NO. OF RECORDS: **360**
RS-232 REPORT: **OFF**
COMPACT REPORT: **OFF**
CHANNEL ENABLED: **ON**

NAME: **CALDAT**
EVENT: SLPCHG
PARAMETERS: **3**
NO. OF RECORDS:**200**
RS-232 REPORT: **OFF**
COMPACT REPORT: **OFF**
CHANNEL ENABLED: **ON**
CAL HOLD OFF: **OFF**

NAME: **DETAIL**
EVENT: **ATIMER**
PARAMETERS: **14**
STARTING DATE: **01-JAN-07**
SAMPLE PERIOD: **000:00:01**
REPORT PERIOD: **000:01:00**
NO. OF RECORDS: **480**
RS-232 REPORT: **OFF**
COMPACT REPORT: **OFF**
CHANNEL ENABLED: **ON**

NAME: **FAST**
EVENT: **ATIMER**
PARAMETERS: **14**
STARTING DATE: **01-JAN-07**
SAMPLE PERIOD: **000:00:01**
REPORT PERIOD: **000:00:01**
NO. OF RECORDS:**360**
RS-232 REPORT: **OFF**
COMPACT REPORT: **OFF**
CHANNEL ENABLED: **ON**

Same parameters &
settings as **DETAIL**

PARAMETER: **CONC1**
MODE: **AVG**
PRECISION: **1**
STORE NUM SAMPLES **OFF**

PARAMETER: **STABIL**
MODE: **AVG**
PRECISION: **2**
STORE NUM SAMPLES **OFF**

PARAMETER: **SMPFLW**
MODE: **AVG**
PRECISION: **1**
STORE NUM SAMPLES **OFF**

PARAMETER: **SMPPRS**
MODE: **AVG**
PRECISION: **1**
STORE NUM SAMPLES **OFF**

PARAMETER: **SLOPE1**
MODE: **INST**
PRECISION:**3**
STORE NUM SAMPLES **OFF**

PARAMETER: **OFSET1**
MODE: **INST**
PRECISION: **1**
STORE NUM SAMPLES **OFF**

PARAMETER: **ZSCNC1**
MODE: **INST**
PRECISION: **1**
STORE NUM SAMPLES **OFF**

Figure 7-1: Default DAS Channels Setup

7.2.1. VIEWING DAS DATA AND SETTINGS

DAS data and settings can be viewed on the front panel through the following control button sequence.

Figure 7-2: DAS – Data Acquisition Menu

7.2.2. EDITING DAS DATA CHANNELS

Although DAS configuration is most conveniently done through the APICOM remote control program (refer to Section 6.12.2.8), the following illustrations shows how to edit DAS channels using the analyzer's front panel control buttons.
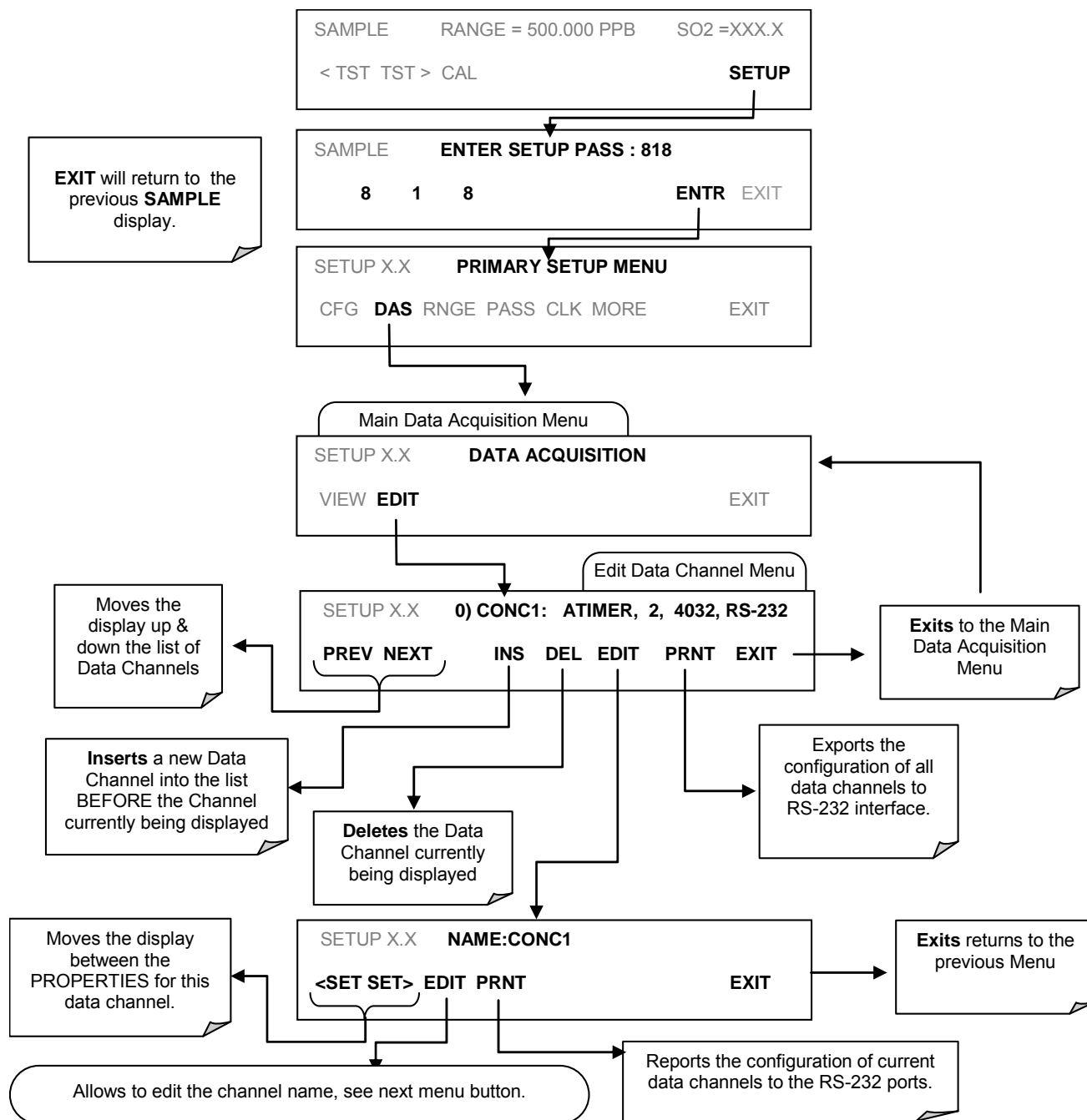
Figure 7-3: DAS – Editing DAS Data Channels

When editing the data channels, the top line of the display indicates some of the configuration parameters. For example, the display line:

0) CONC: ATIMER, 4, 800

represents to the following configuration:

CHANNEL NUMBER.: **0**
NAME: **CONC**
TRIGGER EVENT: **ATIMER**
PARAMETERS: **Four** parameters are included in this channel
EVENT: This channel is set up to record **800** data points.

To edit the name of a data channel, refer to Figure 7-3, then press:
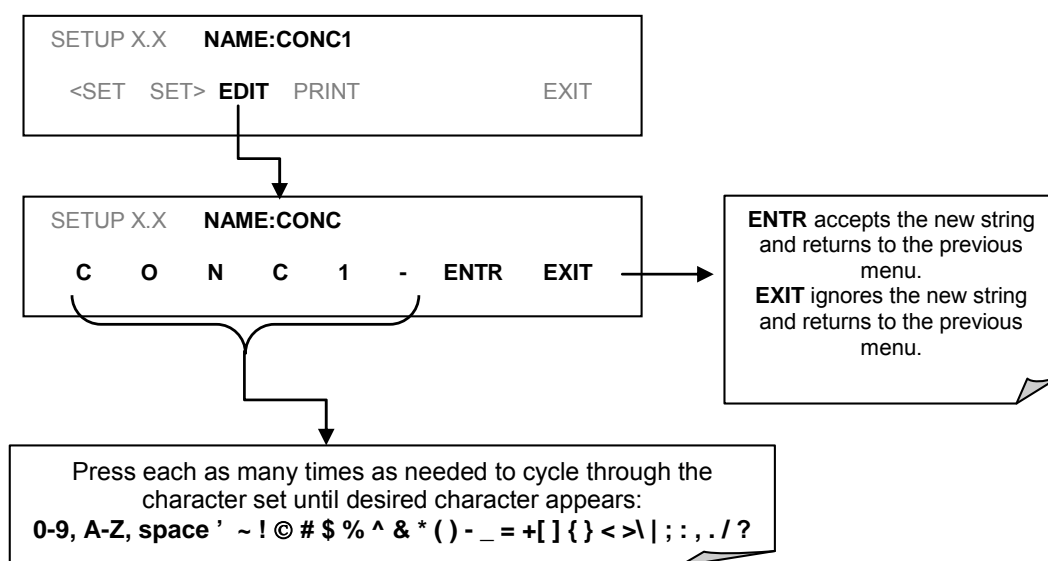
Figure 7-4: DAS – Editing Data Channel Name

7.2.3. TRIGGER EVENTS

To edit the list of data parameters associated with a specific data channel, refer to the DATA Acquisition Menu (refer to Figure 7-2), then press:
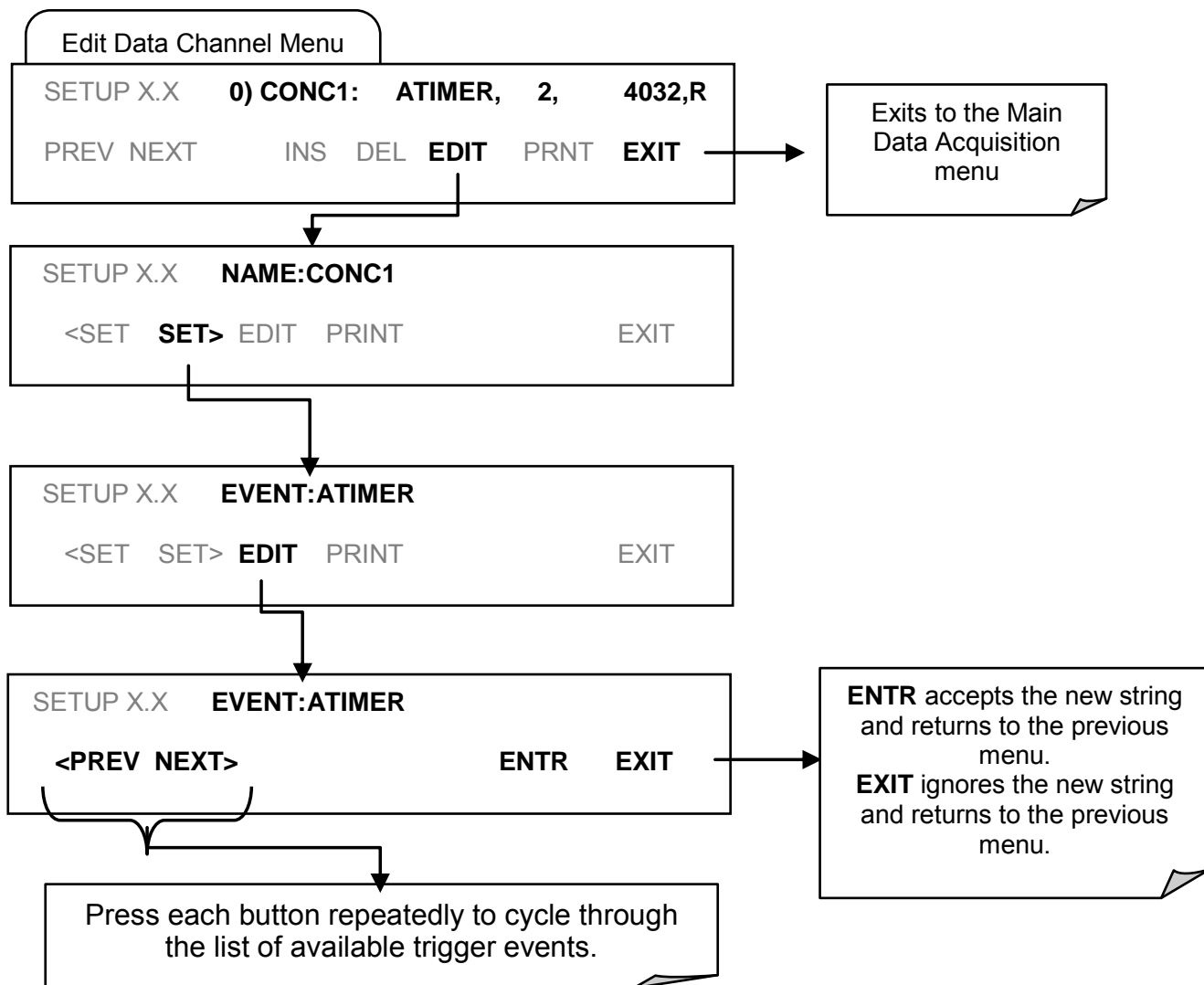
Figure 7-5: DAS – Trigger Events

7.2.4. EDITING DAS PARAMETERS

Data channels can be edited individually from the front panel without affecting other data channels. However, when editing a data channel, such as during adding, deleting or editing parameters, all data for that particular channel will be lost, because the DAS can store only data of one format (number of parameter columns etc.) for any given channel. In addition, a DAS configuration can only be uploaded remotely as an entire set of channels. Hence, remote update of the DAS will always delete all current channels and stored data.

To modify, add or delete a parameter, follow the instruction shown in Figure 7-3, then press:
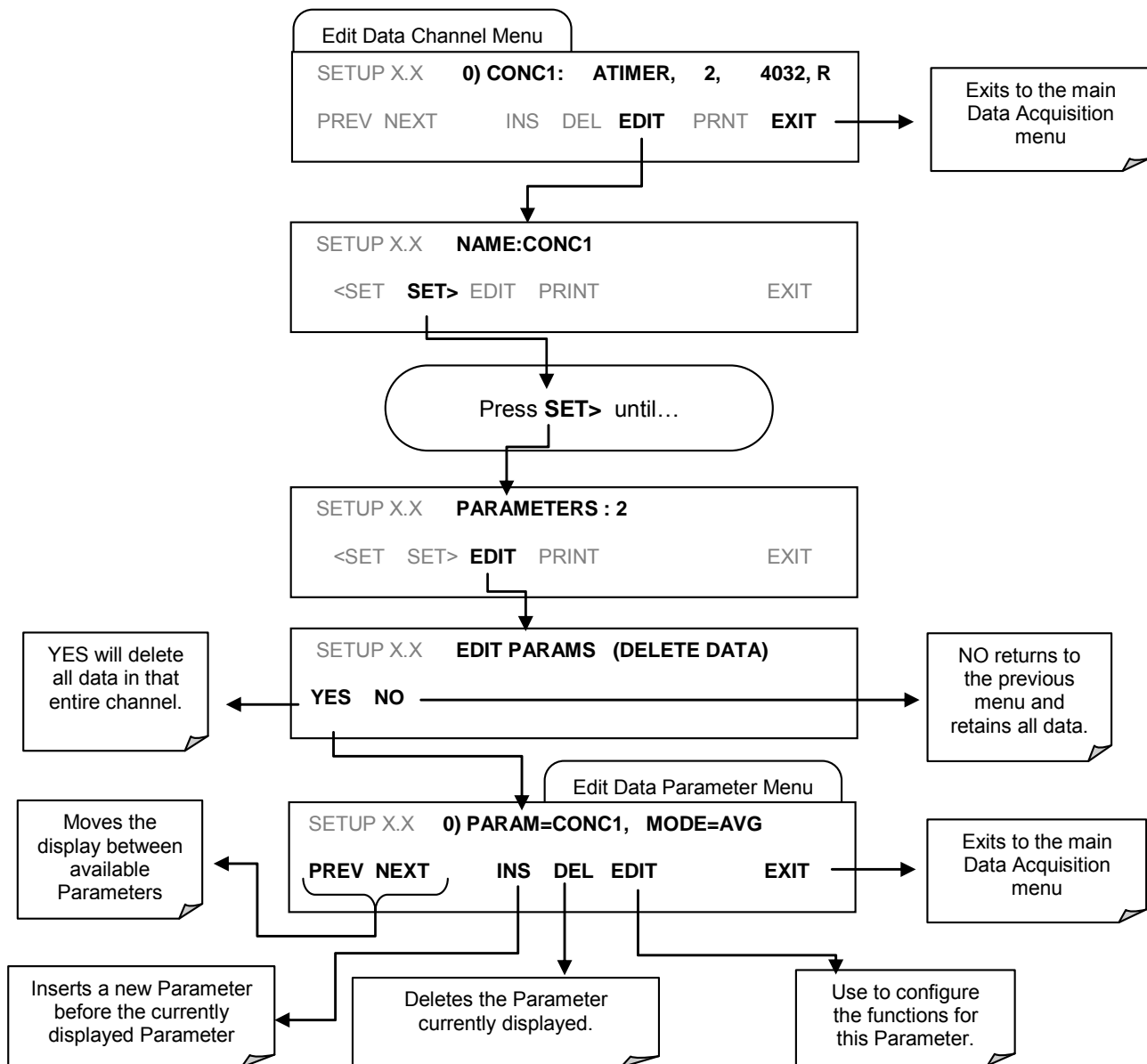
Figure 7-6: DAS – Editing DAS Parameters

To configure the parameters for a specific data parameter, follow the instructions as shown in Figure 7-6, then press:

SETUP X.X   **0) PARAM=CONC1, MODE=AVG**

PREV NEXT   INS DEL EDIT   EXIT

SETUP X.X   **PARAMETERS:CONC1**

SET> EDIT   EXIT

SETUP X.X   **PARAMETERS: CONC1**

PREV NEXT   ENTR   EXIT

Cycle through list of available Parameters.

SETUP X.X   **SAMPLE MODE:AVG**

<SET SET>   EDIT   EXIT

SETUP X.X   **SAMPLE MODE: AVG**

INST AVG SDEV MIN   MAX   ENTR   EXIT

Press any button for the desired mode

SETUP X.X   **PRECISION: 1**

<SET SET>   EDIT   EXIT

SETUP X.X   **PRECISION: 1**

1   ENTR   EXIT

Set for 0-4

ENTR accepts the new setting and returns to the previous menu.
EXIT ignores the new setting and returns to the previous

SETUP X.X   **STORE NUM. SAMPLES: OFF**

<SET   EDIT   EXIT

SETUP X.X   **STORE NUM. SAMPLES: OFF**

OFF   ENTR   EXIT

<SET Returns to previous Functions

Turn ON or OFF

Figure 7-7: DAS – Configuring Parameters for a Specific Data Parameter

7.2.5. SAMPLE PERIOD AND REPORT PERIOD

The DAS defines two principal time periods by which sample readings are taken and permanently recorded:

SAMPLE PERIOD: Determines how often DAS temporarily records a sample reading of the parameter in volatile memory. The **SAMPLE PERIOD** is set to one minute by default and generally cannot be accessed from the standard DAS front panel menu, but is available via the instruments communication ports by using APICOM or the analyzer's standard serial data protocol. **SAMPLE PERIOD** is only used when the DAS parameter's sample mode is set for **AVG, MIN** or **MAX**.

REPORT PERIOD: Sets how often the sample readings stored in volatile memory are processed, (e.g. average, minimum or maximum are calculated) and the results stored permanently in the instrument's Disk-on-Module as well as transmitted via the analyzer's communication ports. The **REPORT PERIOD** may be set from the front panel.

If the **INST** sample mode is selected the instrument stores and reports an instantaneous reading of the selected parameter at the end of the chosen **REPORT PERIOD**

In **AVG, MIN** or **MAX** sample modes, the settings for the **SAMPLE PERIOD** and the **REPORT PERIOD** determine the number of data points used each time the average, minimum or maximum is calculated, stored and reported to the COMM ports. The actual sample readings are not stored past the end of the of the chosen **REPORT PERIOD**.

Also, the **SAMPLE PERIOD** and **REPORT PERIOD** intervals are synchronized to the beginning and end of the appropriate interval of the instruments internal clock.

If **SAMPLE PERIOD** were set for one minute the first reading would occur at the beginning of the next full minute according to the instrument's internal clock.

If the **REPORT PERIOD** were set for of one hour the first report activity would occur at the beginning of the next full hour according to the instrument's internal clock.

EXAMPLE: Given the above settings, if DAS were activated at 7:57:35 the first sample would occur at 7:58 and the first report would be calculated at 8:00 consisting of data points for 7:58. 7:59 and 8:00.

During the next hour (from 8:01 to 9:00) the instrument will take a sample reading every minute and include 60 sample readings.

When the **STORE NUM. SAMPLES** feature is turned on the instrument will also store how many sample readings were used for the **AVG, MIN** or **MAX** calculation but not the readings themselves.

REPORT PERIODS IN PROGRESS WHEN INSTRUMENT IS POWERED OFF

If the instrument is powered off in the middle of a **REPORT PERIOD**, the samples accumulated so far during that period are lost.   Once the instrument is turned back on, the DAS restarts taking samples and temporarily them in volatile memory as part of the **REPORT PERIOD** currently active at the time of restart. At the end of this **REPORT PERIOD** only the sample readings taken since the instrument was turned back on will be included in any **AVG**, **MIN** or **MAX** calculation. Also, the **STORE NUM. SAMPLES** feature will report the number of sample readings taken since the instrument was restarted.

To define the **REPORT PERIOD**, follow the instruction shown in Figure 7-3, then press:
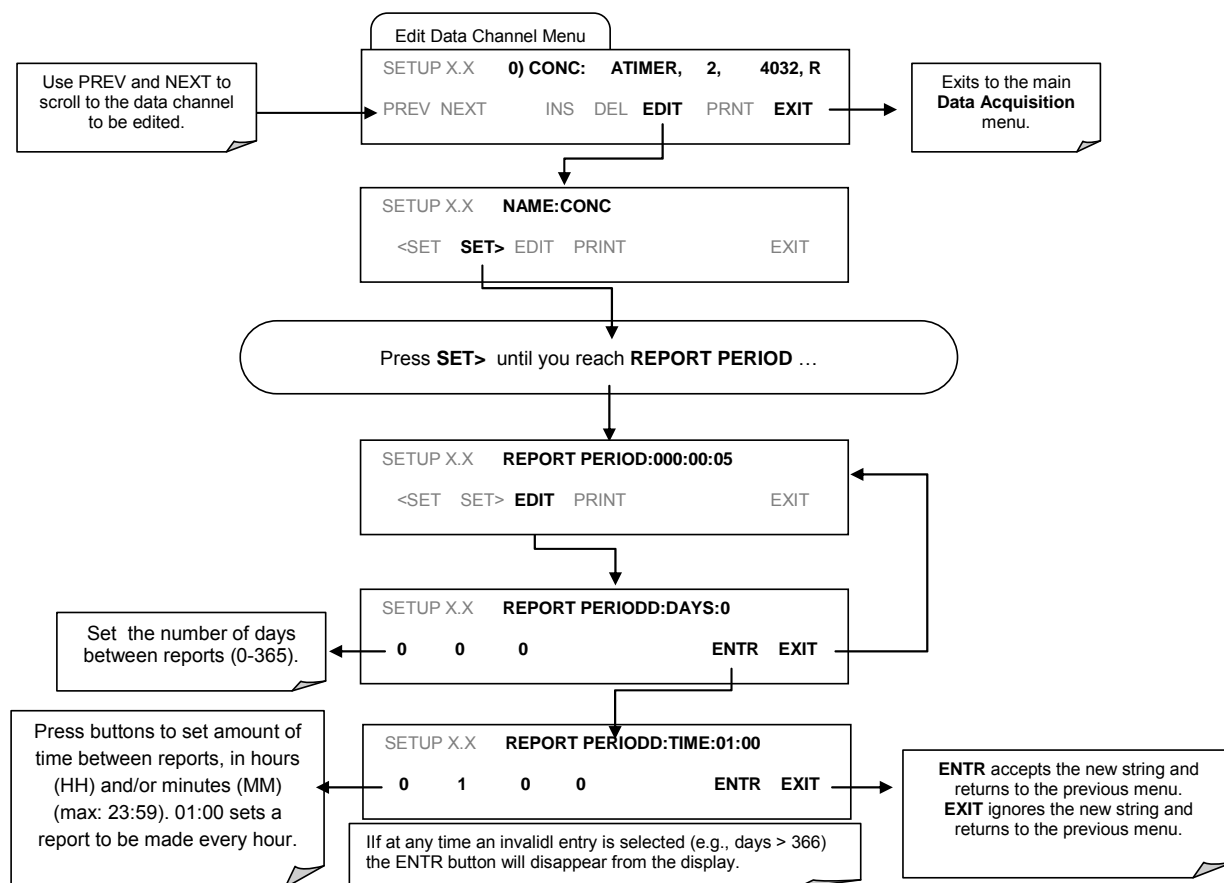
Figure 7-8: DAS – Define the Report Period

7.2.6. NUMBER OF RECORDS

Although the DAS is capable of capturing several months worth of data,, the actual number of records is also limited by the total number of parameters and channels and other settings in the DAS configuration. Every additional data channel, parameter, number of samples setting etc. will reduce the maximum amount of data points somewhat. In general, however, the maximum data capacity is divided amongst all channels (max: 20) and parameters (max: 50 per channel).

The DAS will check the amount of available data space and prevent the user from specifying too many records at any given point. If, for example, the DAS memory space can accommodate 375 more data records, the ENTR button will disappear when trying to specify more than that number of records. This check for memory space may also make an upload of a DAS configuration with APICOM or a Terminal program fail, if the combined number of records would be exceeded. In this case, it is suggested to either try from the front panel what the maximum number of records can be or use trial-and-error in designing the DAS script or calculate the number of records using the DAS or APICOM manuals. To set the number of records for one channel from the front panel, press SETUP-DAS-EDIT-ENTR and the following control button sequence.

Edit Data Channel Menu

SETUP X.X **0) CONC: ATIMER,   2,   900**

PREV NEXT   INS DEL **EDIT** PRNT **EXIT**

Exits to the main
Data Acquisition
menu

SETUP X.X   **NAME:CONC**

<SET **SET>** EDIT PRINT   EXIT

Press **SET>** until…

SETUP X.X   **NUMBER OF RECORDS:4032**

<SET   SET> **EDIT** PRINT   EXIT

SETUP X.X   **EDIT RECORDS (DELETEs DATA)?**

YES   NO

NO returns to the
previous menu.

YES will delete all data
in this channel.

Toggle buttons to set
number of records
(1-99999)

SETUP X.X   **NUMBER OF RECORDS:4032**

0   4   0   3   2   ENTR EXIT

ENTR accepts the new
setting and returns to the
previous menu.
EXIT ignores the new setting
and returns to the previous
menu.

Figure 7-9: DAS – Edit Number of Records

7.2.7. RS-232 REPORT FUNCTION

The M DAS can automatically report data to the communications ports, where they can be captured with a terminal emulation program or simply viewed by the user.

To enable automatic COMM port reporting, follow the instruction shown in Figure 7-3, then press:
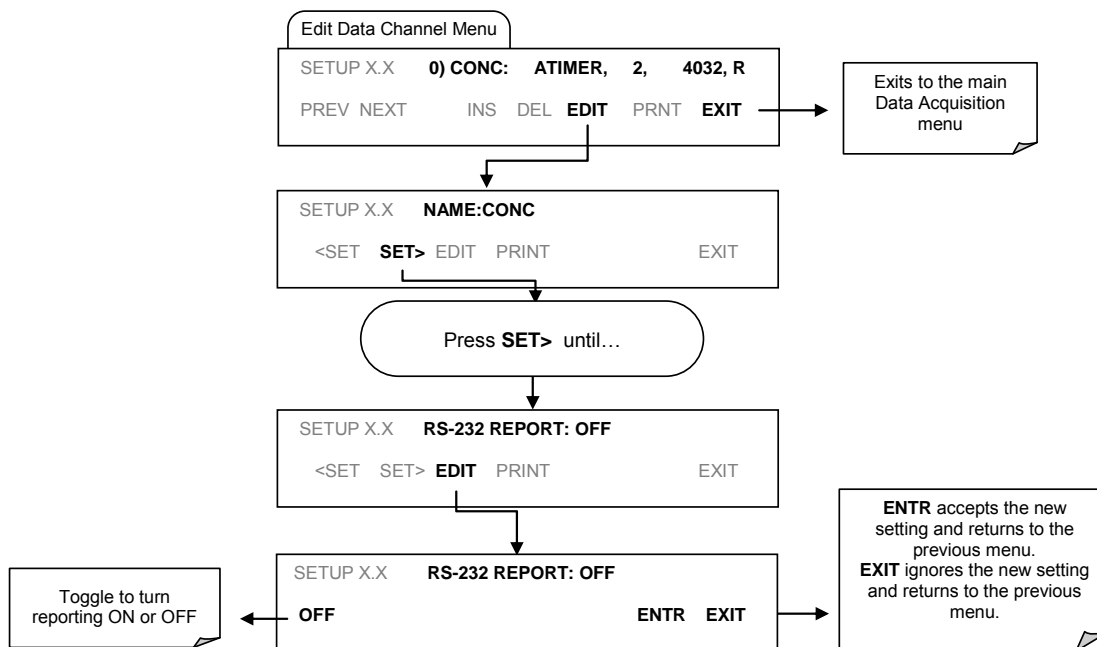
Figure 7-10:   DAS – RS-232 Report Function

7.2.8. COMPACT REPORT

When enabled, this option avoids unnecessary line breaks on all RS-232 reports. Instead of reporting each parameter in one channel on a separate line, up to five parameters are reported in one line, instead.

7.2.9. STARTING DATE

This option allows a user to specify a starting date for any given channel in case the user wants to start data acquisition only after a certain time and date. If the **Starting Date** is in the past, the DAS ignores this setting.

7.2.10. DISABLING/ENABLING DATA CHANNELS

Data channels can be temporarily disabled, which can reduce the read/write wear on the disk-on-module. The ALL_01 channel of the T100, for example, is disabled by default.

To disable a data channel, follow the instruction shown in Figure 7-3, then press:
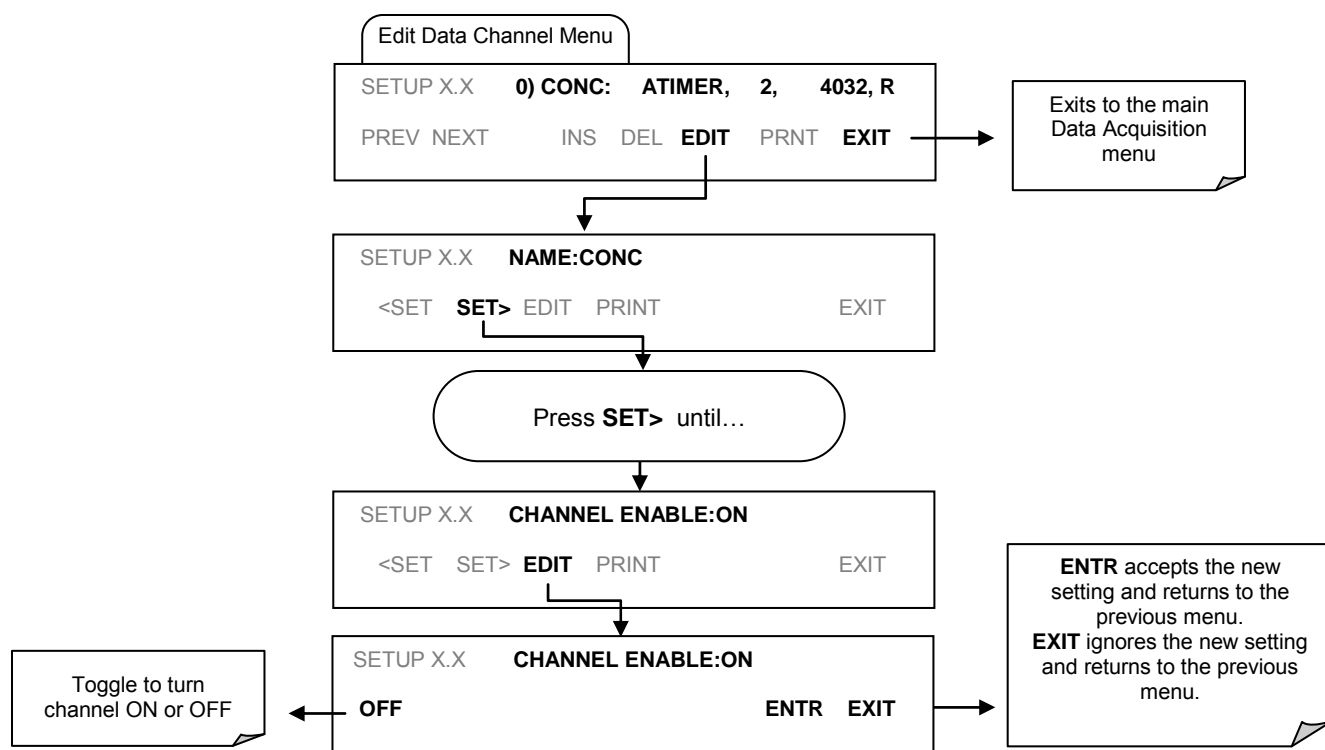
Figure 7-11:   DAS – Disabling / Enabling Data Channels

7.2.11. HOLDOFF FEATURE

The DAS HOLDOFF feature allows to prevent data collection during calibrations and during the DAS_HOLDOFF period enabled and specified in the VARS (refer to Section 6.8).

To enable or disable the HOLDOFF, follow the instruction shown in Figure 7-3, then press:
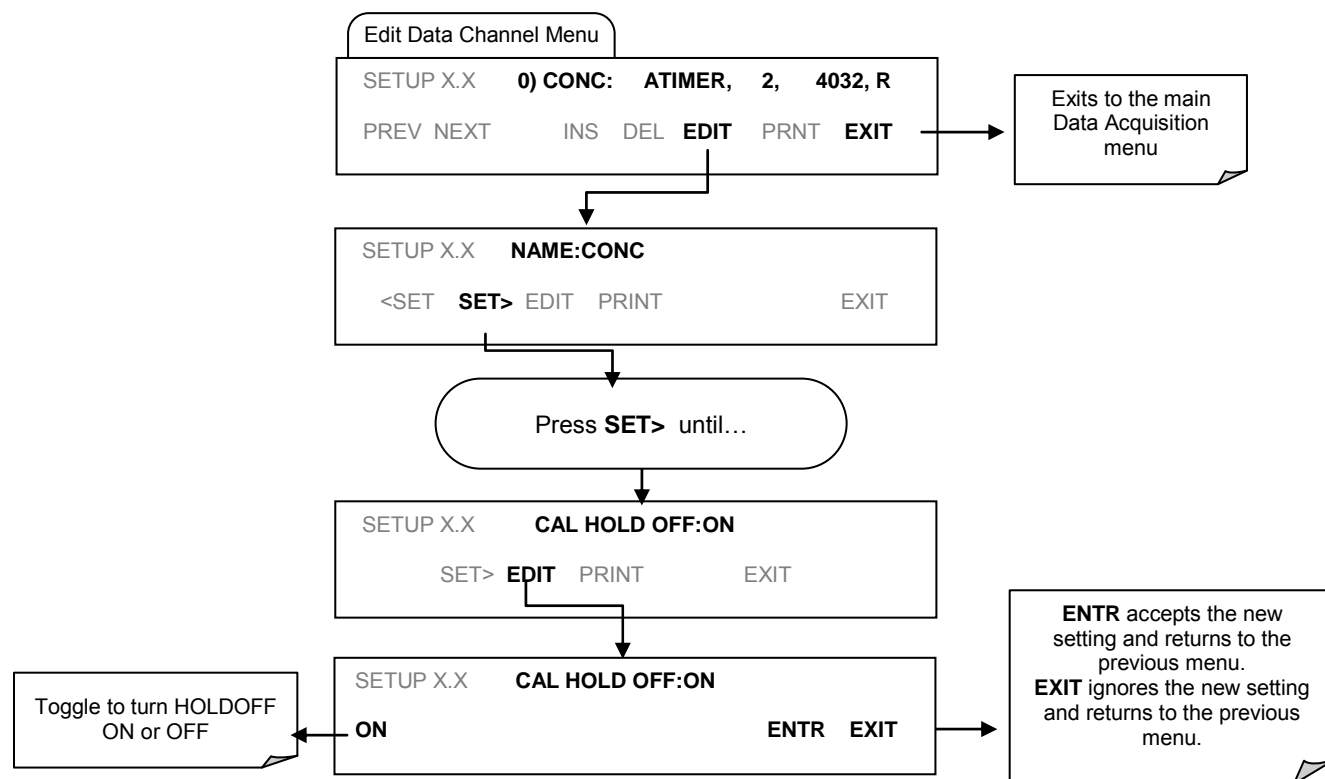
Figure 7-12:   DAS – Holdoff Feature

The DAS can be configured and operated remotely via the APICOM program. Section introduces APICOM and then describes how to

7.3. APICOM REMOTE CONTROL PROGRAM

APICOM is an easy-to-use, yet powerful interface program that allows a user to access and control any of Teledyne API's main line of ambient and stack-gas instruments from a remote connection through direct cable, modem or Ethernet. Running APICOM, a user can:

- Establish a link from a remote location to the T100 through direct cable connection via RS-232 modem or Ethernet.

- View the instrument's front panel and remotely access all functions that could be accessed when standing in front of the instrument.

- Remotely edit system parameters and set points.

- Download, view, graph and save data for predictive diagnostics or data analysis.

- Retrieve, view, edit, save and upload DAS configurations (Section 7.4).

- Check on system parameters for trouble-shooting and quality control.

APICOM is very helpful for initial setup, data analysis, maintenance and troubleshooting. Figure 7-15 shows an example of APICOM being used to remotely configuration the DAS feature. Figure 7-13 shows examples of APICOM's main interface, which emulates the look and functionality of the instruments actual front panel:
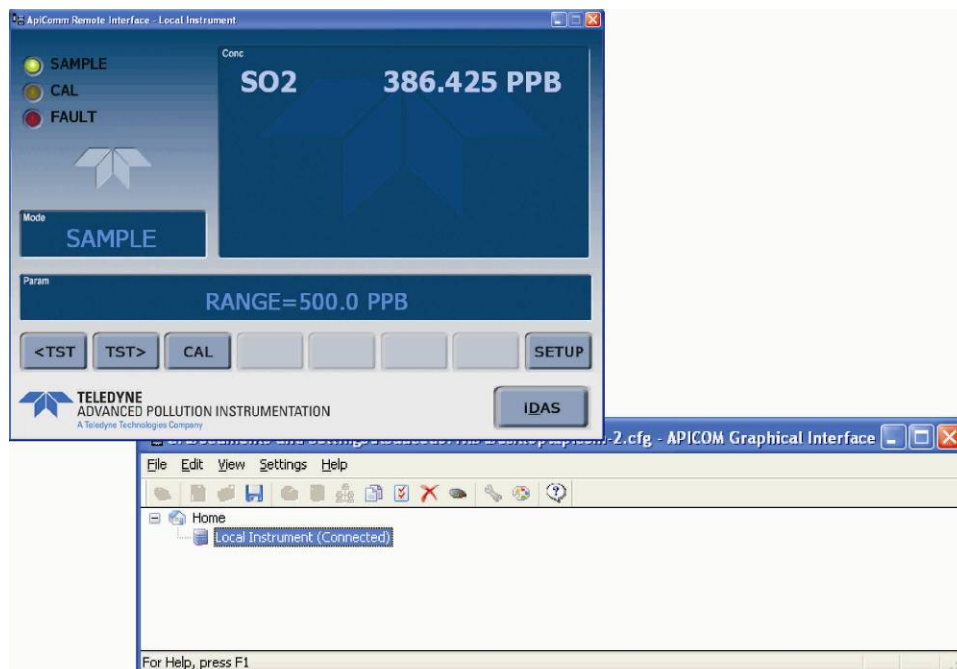
Figure 7-13:   APICOM Remote Control Program Interface

APICOM is included free of cost with the analyzer and the latest versions can also be downloaded for free at http://www.teledyne-api.com/software/apicom/.

7.4. REMOTE DAS CONFIGURATION VIA APICOM

Editing channels, parameters and triggering events as described in this section is performed via the APICOM remote control program using the graphic interface similar to the example shown in Figure 7-14. Refer to Section 8 for details on remote access to the T100 analyzer.
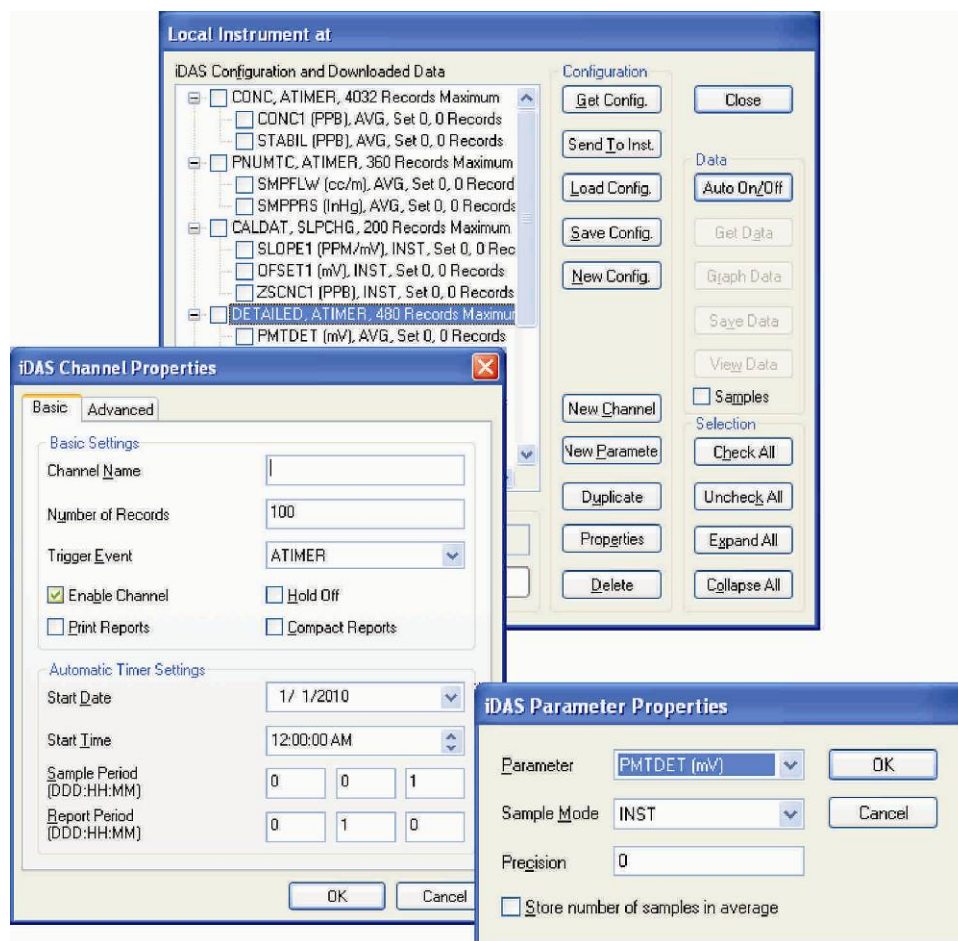
Figure 7-14:   Sample APICOM User Interface for Configuring the DAS

Once a DAS configuration is edited (which can be done offline and without interrupting DAS data collection), it is conveniently uploaded to the instrument and can be stored on a computer for later review, alteration or documentation and archival. Refer to the APICOM manual for details on these procedures. The APICOM user manual (Teledyne API's P/N 039450000) is included in the APICOM installation file, which can be downloaded at http://www.teledyne-api.com/software/apicom/.

Although Teledyne API recommends the use of APICOM, the DAS can also be accessed and configured through a terminal emulation program such as HyperTerminal (refer to Figure 7-15). However, all configuration commands must be created following a strict syntax or be pasted in from of a text file, which was edited offline and then uploaded through a specific transfer procedure.
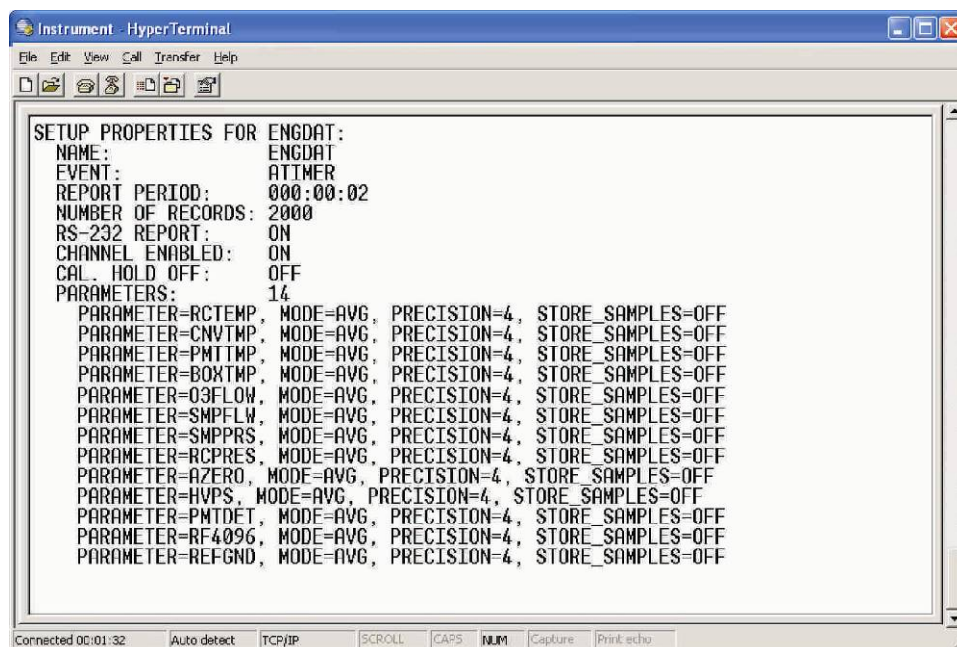
Figure 7-15:   DAS Configuration Through a Terminal Emulation Program

Both procedures are best started by downloading the default DAS configuration, getting familiar with its command structure and syntax conventions, and then altering a copy of the original file offline before uploading the new configuration.

IMPORTANT	IMPACT ON READINGS OR DATA
	Whereas the editing, adding and deleting of DAS channels and parameters of one channel through the front-panel control buttons can be done without affecting the other channels, uploading a DAS configuration script to the analyzer through its communication ports will erase all data, parameters and channels by replacing them with the new DAS configuration. Backup of data and the original DAS configuration is advised before attempting any DAS changes.

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8. REMOTE OPERATION OF THE ANALYZER

This section provides information needed when using external digital and serial I/O and when using Hessen protocol for remote operation. It also provides references to communications-related manuals.

8.1. REMOTE OPERATION USING THE EXTERNAL DIGITAL I/O

8.1.1. STATUS OUTPUTS

The status outputs report analyzer conditions via optically isolated NPN transistors, which sink up to 50 mA of DC current. These outputs can be used interface with devices that accept logic-level digital inputs, such as programmable logic controllers (PLC's). Each Status bit is an open collector output that can withstand up to 40 VDC. All of the emitters of these transistors are tied together and available at D.

ATTENTION

> **COULD DAMAGE INSTRUMENT AND VOID WARRANTY**
>
> **Most PLC's have internal provisions for limiting the current that the input will draw from an external device. When connecting to a unit that does not have this feature, an external dropping resistor must be used to limit the current through the transistor output to less than 50 mA. At 50 mA, the transistor will drop approximately 1.2V from its collector to emitter.**

The status outputs are accessed through a 12 pin connector on the analyzer's rear panel labeled STATUS (refer to Figure 3-4). The function of each pin is defined in Table 8-1.
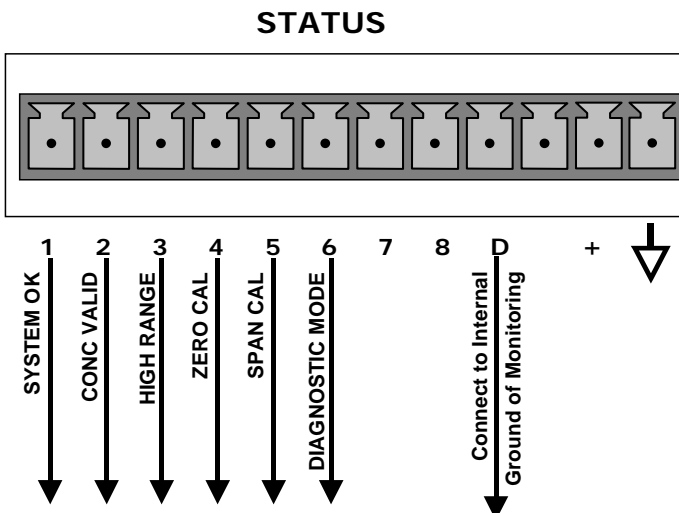
STATUS

Figure 8-1: Status Output Connector

Table 8-1: Status Output Pin Assignments

CONNECTOR PIN	STATUS	CONDITION (ON=CONDUCTING)
1	System Ok	ON if no faults are present.
2	Conc Valid	ON if concentration measurement is valid, OFF when invalid.
3	High Range	ON if unit is in high range of any AUTO range mode.
4	Zero Cal	ON whenever the instrument is in ZERO calibration mode.
5	Span Cal	ON whenever the instrument is in SPAN calibration mode.
6	Diag Mode	ON whenever the instrument is in DIAGNOSTIC mode.
7-8		Unused
D	Emitter Bus	The emitters of the transistors on pins 1-8 are bussed together. For most applications, this pin should be connected to the circuit ground of the receiving device.
+	Dc Power	+ 5 VDC source, 30 mA maximum (combined rating with Control Inputs)
▽	Digital Ground	The ground from the analyzer's internal, 5/±15 VDC power supply.

8.1.2. CONTROL INPUTS

Control inputs allow the user to remotely initiate ZERO and SPAN calibration modes are provided through a 10-pin connector labeled CONTROL IN on the analyzer's rear panel. These are opto-isolated, digital inputs that are activated when a 5 VDC signal from the "U" pin is connected to the respective input pin.

Table 8-2: Control Input Pin Assignments

INPUT	STATUS	CONDITION WHEN ENABLED
A	External Zero Cal	Zero calibration mode is activated. The mode field of the display will read ZERO CAL R.
B	External Span Cal	Span calibration mode is activated. The mode field of the display will read SPAN CAL R.
C		Unused
D		Unused
E		Unused
F		Unused
⏚	Digital Ground	Provided to ground an external device (e.g., recorder).
U	DC Power For Input Pull Ups	Input for +5 VDC required to activate inputs A - F. This voltage can be taken from an external source or from the "+" pin.
+	Internal +5v Supply	Internal source of +5V which can be used to activate inputs when connected to pin U.

There are two methods to activate control inputs. The internal +5V available from the "+" pin is the most convenient method (Figure 8-2). However, to ensure that these inputs are truly isolated, a separate, external 5 VDC power supply should be used (Figure 8-3).
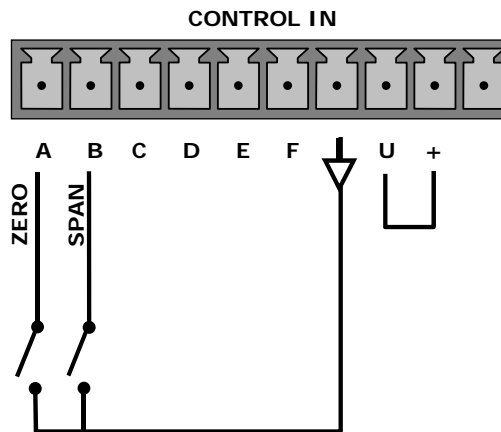
Figure 8-2: Control Inputs with Local 5 V Power Supply
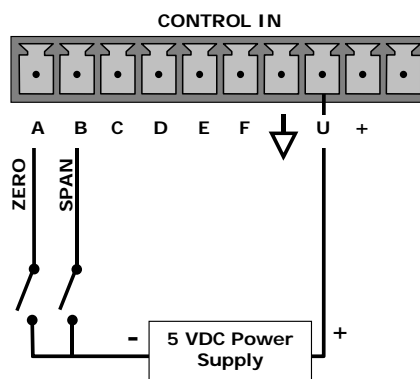
Figure 8-3: Control Inputs with External 5 V Power Supply

8.2. REMOTE OPERATION USING THE EXTERNAL SERIAL I/O

8.2.1. TERMINAL OPERATING MODES

The T100 can be remotely configured, calibrated or queried for stored data through the serial ports. As terminals and computers use different communication schemes, the analyzer supports two communication modes specifically designed to interface with these two types of devices.

Computer mode is used when the analyzer is connected to a computer with a dedicated interface program such as APICOM. More information regarding APICOM can be found in later in this section or on the Teledyne API's website at http://www.teledyne-api.com/software/apicom/.

Interactive mode is used with a terminal emulation programs such as HyperTerminal or a "dumb" computer terminal. The commands that are used to operate the analyzer in this mode are listed in Table 8-3 and in Appendix A-6.

8.2.2. HELP COMMANDS IN TERMINAL MODE

Table 8-3: Terminal Mode Software Commands

Command	Function
Control-T	Switches the analyzer to terminal mode (echo, edit). If mode flags 1 & 2 are OFF, the interface can be used in interactive mode with a terminal emulation program.
Control-C	Switches the analyzer to computer mode (no echo, no edit).
CR (carriage return)	A carriage return is required after each command line is typed into the terminal/computer. The command will not be sent to the analyzer to be executed until this is done. On personal computers, this is achieved by pressing the ENTER button.
BS (backspace)	Erases one character to the left of the cursor location.
ESC (escape)	Erases the entire command line.
? [ID] CR	This command prints a complete list of available commands along with the definitions of their functionality to the display device of the terminal or computer being used. The ID number of the analyzer is only necessary if multiple analyzers are on the same communications line, such as the multi-drop setup.
Control-C	Pauses the listing of commands.
Control-P	Restarts the listing of commands.

8.2.3. COMMAND SYNTAX

Commands are not case-sensitive and all arguments within one command (i.e. ID numbers, keywords, data values, etc.) must be separated with a space character.

All Commands follow the syntax:

X [ID] COMMAND <CR>

Where:

X   is the command type (one letter) that defines the type of command. Allowed designators are listed in Table 6-25 and Appendix A-6.

[ID]   is the analyzer identification number (refer to Section 6.10.1.). Example: the Command "? 200" followed by a carriage return would print the list of available commands for the revision of software currently installed in the instrument assigned ID Number 200.

COMMAND is the command designator: This string is the name of the command being issued (LIST, ABORT, NAME, EXIT, etc.). Some commands may have additional arguments that define how the command is to be executed. Press? <CR> or refer to Appendix A-6 for a list of available command designators.

<CR>   is a carriage return. All commands must be terminated by a carriage return (usually achieved by pressing the ENTER button on a computer).

Table 8-4: Command Types

COMMAND	COMMAND TYPE
C	Calibration
D	Diagnostic
L	Logon
T	Test measurement
V	Variable
W	Warning

8.2.4. DATA TYPES

Data types consist of integers, hexadecimal integers, floating-point numbers, Boolean expressions and text strings.

Integer data are used to indicate integral quantities such as a number of records, a filter length, etc. They consist of an optional plus or minus sign, followed by one or more digits. For example, *+1*, *-12*, *123* are all valid integers.

Hexadecimal integer data are used for the same purposes as integers. They consist of the two characters "0x," followed by one or more hexadecimal digits (0-9, A-F, a-f), which is the 'C' programming language convention. No plus or minus sign is permitted. For example, *0x1*, *0x12*, *0x1234abcd* are all valid hexadecimal integers.

Floating-point numbers are used to specify continuously variable values such as temperature set points, time intervals, warning limits, voltages, etc. They consist of an optional plus or minus sign, followed by zero or more digits, an optional decimal point, and zero or more digits. (At least one digit must appear before or after the decimal

point.) Scientific notation is not permitted. For example, *+1.0, 1234.5678, -0.1, 1* are all valid floating-point numbers.

Boolean expressions are used to specify the value of variables or I/O signals that may assume only two values. They are denoted by the keywords *ON* and *OFF*.

Text strings are used to represent data that cannot be easily represented by other data types, such as data channel names, which may contain letters and numbers. They consist of a quotation mark, followed by one or more printable characters, including spaces, letters, numbers, and symbols, and a final quotation mark. For example, *"a", "1", "123abc"*, and *"()[]<>"* are all valid text strings. It is not possible to include a quotation mark character within a text string.

Some commands allow you to access variables, messages, and other items, such as DAS data channels, by name. When using these commands, you must type the entire name of the item; you cannot abbreviate any names.

8.2.5. STATUS REPORTING

Reporting of status messages as an audit trail is one of the three principal uses for the RS-232 interface (the other two being the command line interface for controlling the instrument and the download of data in electronic format). You can effectively disable the reporting feature by setting the interface to quiet mode (refer to Section 6.2.1 and Table 6-1.

Status reports include DAS data (when reporting is enabled), warning messages, calibration and diagnostic status messages. Refer to Appendix A-3 for a list of the possible messages, and this section for information on controlling the instrument through the RS-232 interface.

8.2.5.1. GENERAL MESSAGE FORMAT

All messages from the instrument (including those in response to a command line request) are in the format:

X DDD:HH:MM [Id] MESSAGE<CRLF>

Where:

X	is a command type designator, a single character indicating the message type, as shown in the Table 6-25.
DDD:HH:MM	is the time stamp, the date and time when the message was issued. It consists of the Day-of-year (DDD) as a number from 1 to 366, the hour of the day (HH) as a number from 00 to 23, and the minute (MM) as a number from 00 to 59.
[ID]	is the analyzer ID, a number with 1 to 4 digits.
MESSAGE	is the message content that may contain warning messages, test measurements, DAS reports, variable values, etc.
<CRLF>	is a carriage return / line feed pair, which terminates the message.

The uniform nature of the output messages makes it easy for a host computer to parse them into an easy structure. Keep in mind that the front panel display does not give any information on the time a message was issued, hence it is useful to log such messages

for trouble-shooting and reference purposes. Terminal emulation programs such as HyperTerminal can capture these messages to text files for later review.

8.3. REMOTE ACCESS BY MODEM

The T100 can be connected to a modem for remote access. This requires a cable between the analyzer's COM port and the modem, typically a DB-9F to DB-25M cable (available from Teledyne API with P/N WR0000024).

Once the cable has been connected, check to ensure that the DTE-DCE is in the correct position (refer to Section 6.1). Also ensure that the T100 COM port is set for a baud rate that is compatible with the modem, which needs to operate with an 8-bit word length with one stop bit.

The first step is to turn on the **MODEM ENABLE** communication mode (Mode 64, Section 6.2.1). Once this is completed, the appropriate setup command line for your modem can be entered into the analyzer. The default setting for this feature is:

AT Y0 &D0 &H0 &I0 S0=2 &B0 &N6 &M0 E0 Q1 &W0

This string can be altered to match your modem's initialization and can be up to 100 characters long.

To change this setting, access the COMMUNICATIONS Menu (refer to Figure 5-13), then press:
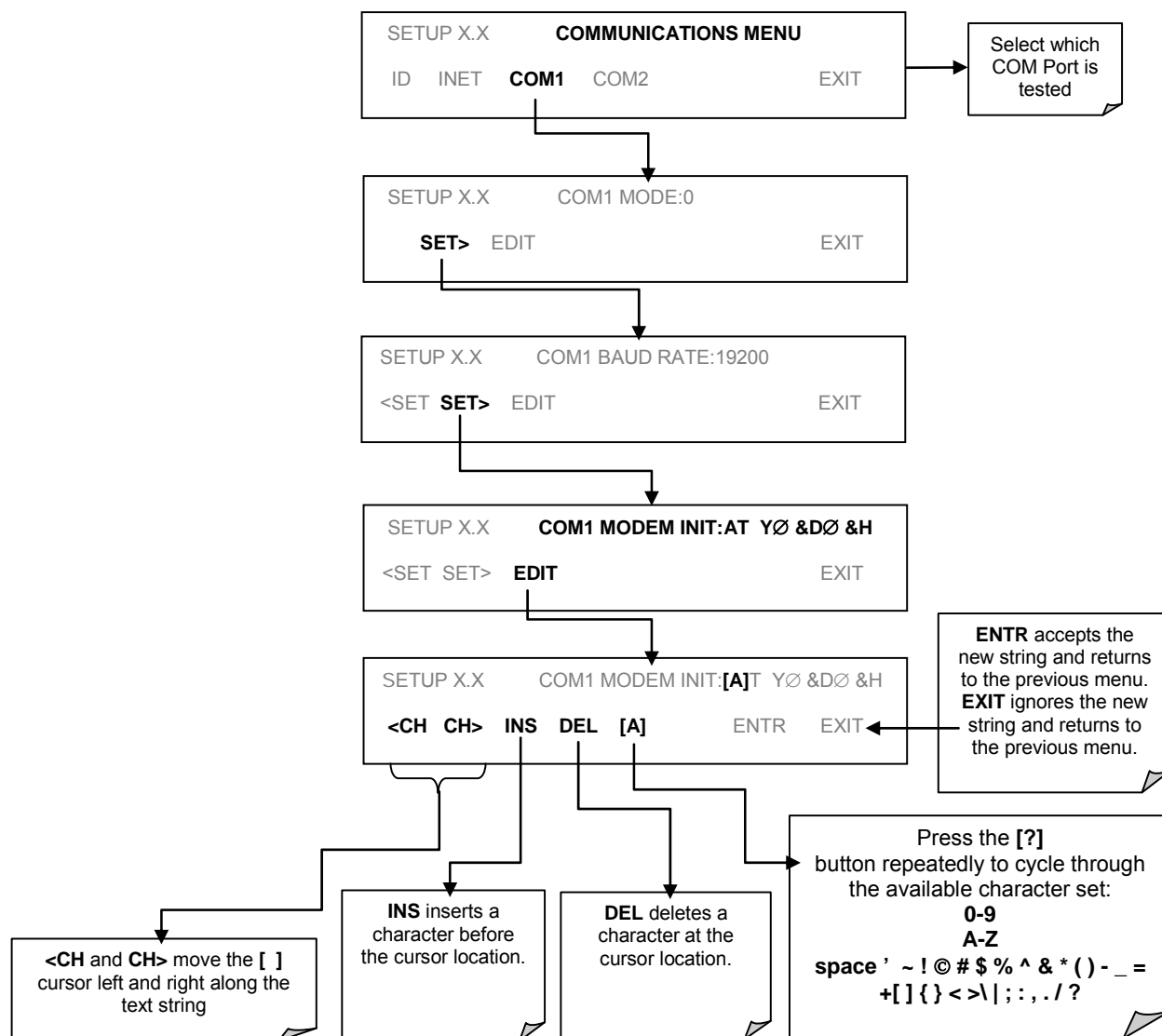
Figure 8-4: COMM – Remote Access by Modem

To initialize the modem, access the COMMUNICATIONS Menu (refer to Figure 5-13), then press:
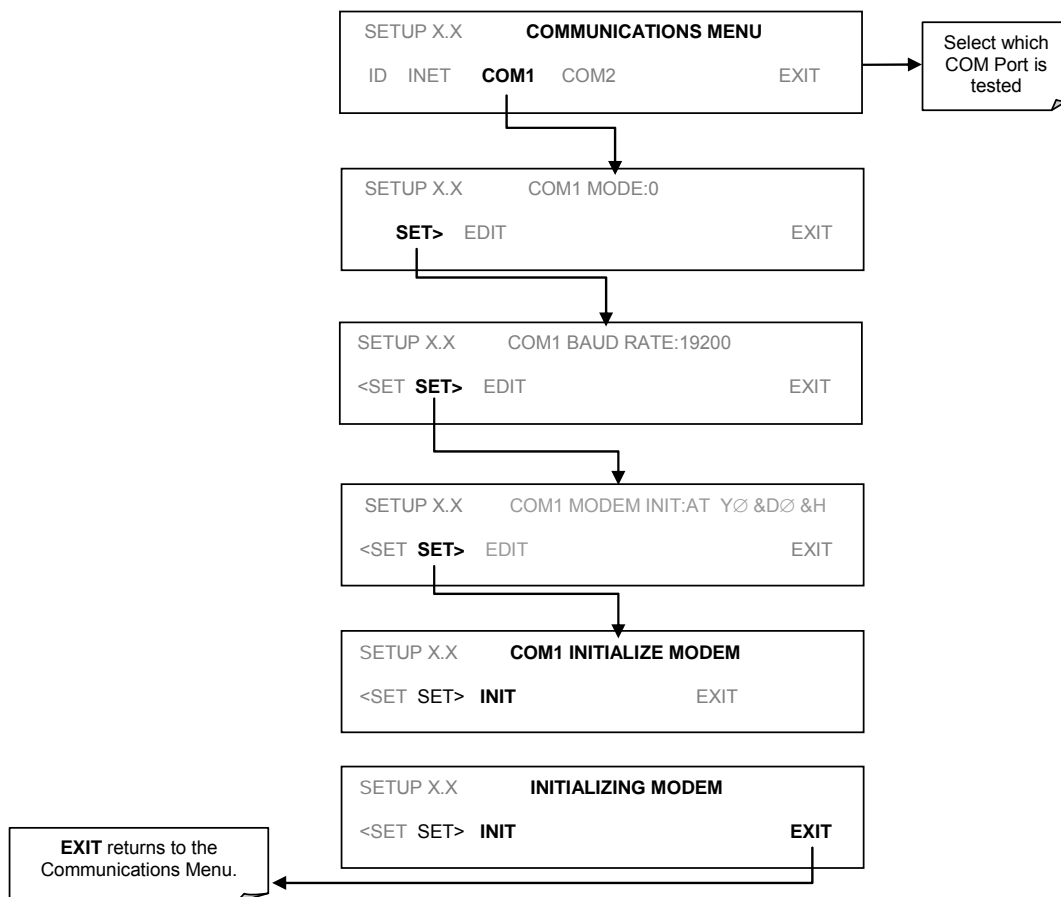
Figure 8-5: COMM – Initialize the Modem

8.4. COM PORT PASSWORD SECURITY

In order to provide security for remote access of the T100, a LOGON feature can be enabled to require a password before the instrument will accept commands. This is done by turning on the **SECURITY MODE** (refer to Section 5.5). Once the **SECURITY MODE** is enabled, the following items apply.

- A password is required before the port will respond or pass on commands.

- If the port is inactive for one hour, it will automatically logoff, which can also be achieved with the LOGOFF command.

- Three unsuccessful attempts to log on with an incorrect password will cause subsequent logins to be disabled for 1 hour, even if the correct password is used.

- If not logged on, the only active command is the '?' request for the help screen.

- The following messages will be returned at logon:

- LOGON SUCCESSFUL - Correct password given

- LOGON FAILED - Password not given or incorrect

- LOGOFF SUCCESSFUL - Connection terminated successfully

To log on to the T100 analyzer with **SECURITY MODE** feature enabled, type:

LOGON 940331

940331 is the default password. To change the default password, use the variable RS-232_PASS issued as follows:

V RS-232_PASS=NNNNNN

Where N is any numeral between 0 and 9.

8.5. ADDITIONAL COMMUNICATIONS DOCUMENTATION

Table 8-5: Serial Interface Documents

Interface / Tool	Document Title	Part Number	Available Online*
APICOM	APICOM User Manual	058130000	YES
DAS Manual	Detailed description of the DAS	028370000	YES
* These documents can be downloaded at http://www.teledyne-api.com/manuals/.			

9. CALIBRATION PROCEDURES

This section describes the calibration procedures for the T100. All of the methods described in this section can be initiated and controlled through the COM ports.

IMPORTANT	**IMPACT ON READINGS OR DATA** **If you are using the T100 for US-EPA controlled monitoring, refer to Section 10 for information on the EPA calibration protocol.**

9.1. CALIBRATION PREPARATIONS

The calibration procedures in this section assume that the analog range and units of measure, range mode, and reporting range have already been selected for the analyzer. If this has not been done, please do so before continuing (refer to Sections 3.4.4.1 and 5 for instructions).

IMPORTANT	**IMPACT ON READINGS OR DATA** **It is recommended that the LAMP CAL routine (refer to Section 5.9.6) be performed prior to all calibration operations. This will allow the instrument to account for minor changes due to aging of the UV lamp.**

9.1.1. REQUIRED EQUIPMENT, SUPPLIES, AND EXPENDABLES

Calibration of the T100 analyzer requires a certain amount of equipment and supplies. These include, but are not limited to, the following:

- Zero-air source
- Sulfur dioxide span gas source
- Gas lines - all gas line materials should be Teflon-type or glass.
- A recording device such as a strip-chart recorder and/or data logger (optional).
- Traceability Standards

9.1.1.1. ZERO AIR

Zero air is similar in chemical composition to the Earth's atmosphere but scrubbed of all components that might affect the analyzer's readings. For SO_2 measuring devices, zero air should be similar in composition to the sample gas but devoid of SO_2 and large amounts of hydrocarbons, nitrogen oxide (NO) and with a water vapor dew point $\leq -15°\,C$.

Devices such as the API Model 701 zero air generator that condition ambient air by drying and removal of pollutants are available. We recommend this type of device for generating zero air.

9.1.1.2. SPAN GAS

Span gas is specifically mixed to match the chemical composition of the gas being measured at about 80% of the desired full measurement range. For example, if the measurement range is 500 ppb, the span gas should have an SO_2 concentration of about 400 ppb.

Span gases should be certified to a specific accuracy to ensure accurate calibration of the analyzer. Typical gas accuracy for SO_2 gases is 1 or 2 %.

- If using a secondary dilution source with zero air through a calibrator, then use a bottle of SO_2 balanced nitrogen.

- If calibrator and zero air source are not available, then use a bottle of SO_2 balanced air.

Teledyne API offers an IZS option operating with permeation devices. The accuracy of these devices is about ±5%. Whereas this may be sufficient for quick, daily calibration checks, we strongly recommend using certified SO_2 span gases for accurate calibration.

IMPORTANT   IMPACT ON READINGS OR DATA

Applications requiring US-EPA equivalency do not allow permeation devices to be used as sources of span gas for calibration of the analyzer.

9.1.1.3. CALIBRATION GAS STANDARDS AND TRACEABILITY

All equipment used to produce calibration gases should be verified against standards of the National Institute for Standards and Technology (NIST). To ensure NIST traceability, we recommend acquiring cylinders of working gas that are certified to be traceable to NIST Standard Reference Materials (SRM). These are available from a variety of commercial sources.

Table 9-1: NIST-SRM's Available for Traceability of SO_2 Calibration Gases

NIST-SRM[4]	TYPE	NOMINAL CONCENTRATION
1693a	Sulfur dioxide in N_2	50 ppm
1694a	Sulfur dioxide in N_2	100 ppm
1661a	Sulfur dioxide in N_2	500 ppm

9.1.2. DATA RECORDING DEVICES

A strip chart recorder, data acquisition system or digital data acquisition system should be used to record data from the T100's serial or analog outputs. If analog readings are used, the response of the recording system should be checked against a NIST traceable voltage source or meter. Data recording device should be capable of bi-polar operation so that negative readings can be recorded. For electronic data recording, the T100 provides an internal data acquisition system (DAS), which is described in detail in Section 0.

IMPORTANT

IMPACT ON READINGS OR DATA

Be aware of the difference between Calibration and Calibration Check: Pressing the ENTR button during the following procedure re-calculates the stored values for OFFSET and SLOPE and alters the instrument's calibration. If you wish to perform a calibration CHECK, do not press ENTR and refer to Section 9.3.

9.2. MANUAL CALIBRATION

The following section describes the basic method for manually calibrating the T100 SO$_2$ analyzer.

STEP ONE: Connect the sources of zero air and span gas as shown below.
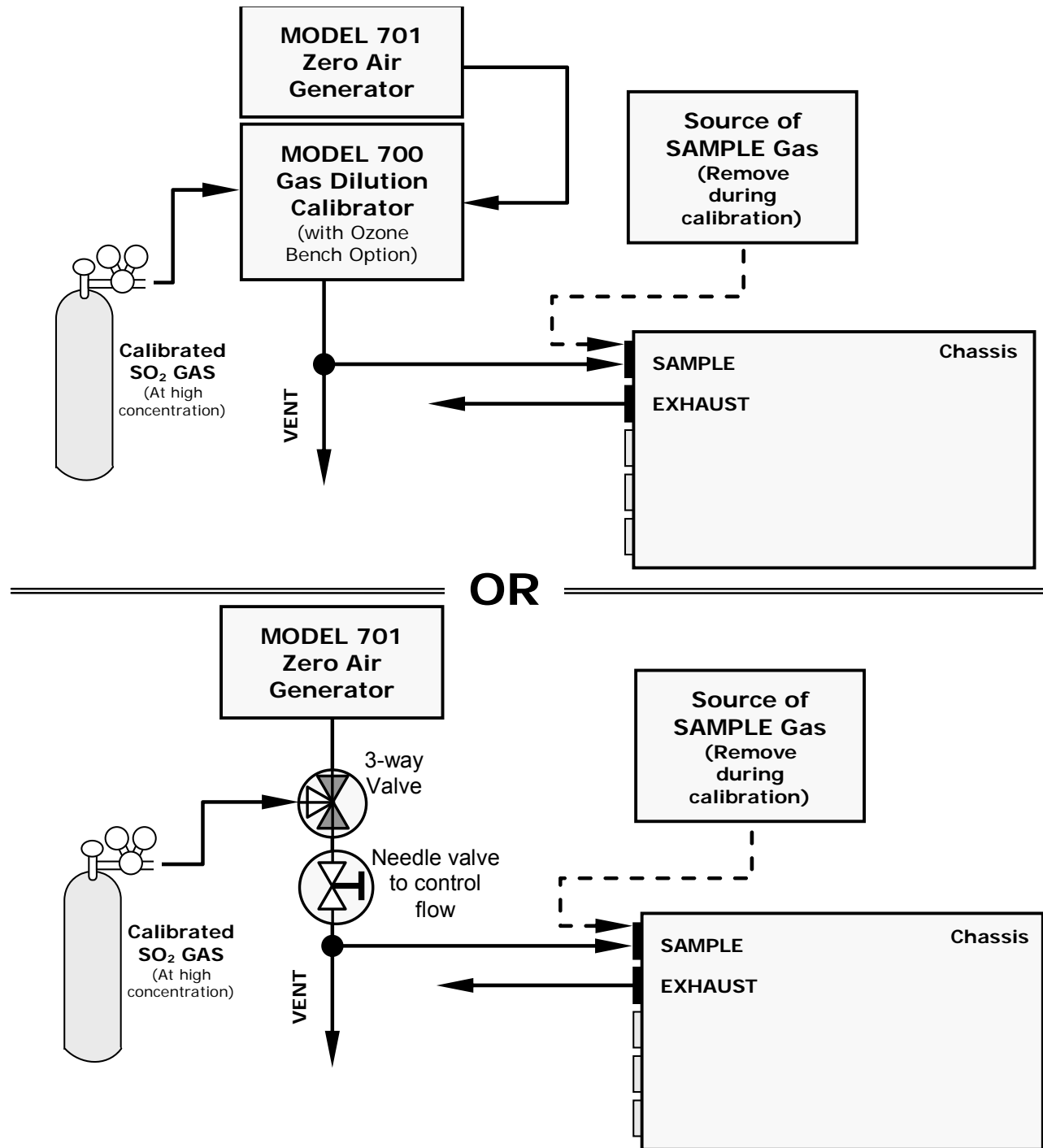
Figure 9-1: Setup for Manual Calibration without Z/S valve or IZS Option (Step 1)

STEP TWO: Set the expected SO_2 span gas concentrations. In this example the instrument is set for single (**SNGL**) range mode with a reporting range span of 500 ppb.
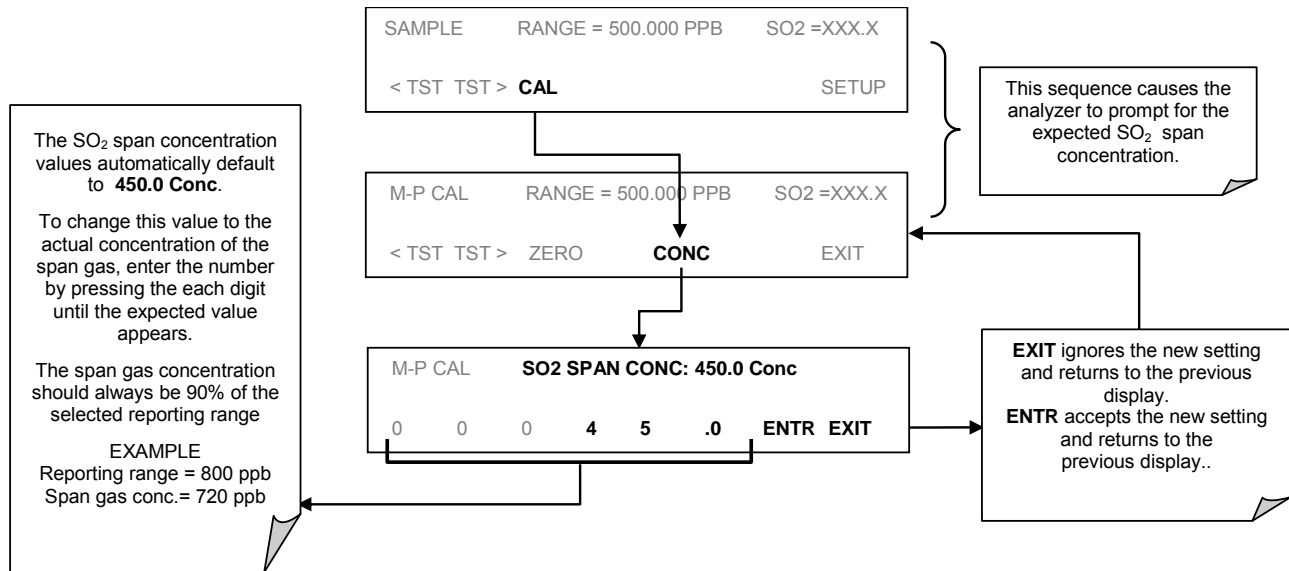
Figure 9-2: Setup for Manual Calibration without Z/S valve or IZS Option (Step 2)

STEP THREE: Perform the zero/span calibration:

SAMPLE   RANGE = 500.0 PPB   SO2 =XXX.X

< TST **TST** > CAL   SETUP

> Set the Display to show the **SO2 STB** test function. This function calculates the stability of the SO$_2$ measurement

SAMPLE   RANGE = 500.0 PPB   SO2 =XXX.X

< TST TST > CAL   SETUP

ACTION:
Allow zero gas to enter the sample port at the rear of the instrument.

> Wait until **SO2 STB** falls below 0.5 ppb. This may take several minutes.

M-P CAL   **SO2 STB=X.XXX PPB**   SO2 =XXX.X

< TST TST > **CAL**   SETUP

M-P CAL   **SO2 STB=X.XXX PPB**   SO2 =XXX.X

< TST TST > **ZERO**   CONC   EXIT

M-P CAL   **SO2 STB=X.XXX PPB**   SO2 =XXX.X

< TST TST > **ENTR**   CONC   **EXIT**

> Press **ENTR** to changes the **OFFSET** & **SLOPE** values for the SO$_2$ measurements.
> Press **EXIT** to leave the calibration unchanged and return to the previous menu.

ACTION:
Allow span gas to enter the sample port at the rear of the instrument.

> The value of **SO2 STB** may jump significantly.
> Wait until it falls back below 0.5 ppb.
> This may take several minutes.

M-P CAL   **SO2 STB=X.XXX PPB**   SO2 =XXX.X

< TST TST >   **SPAN** CONC   EXIT

> The **SPAN** button now appears during the transition from zero to span.
> You may see both the SPAN and the ZERO buttons.

M-P CAL   RANGE = 500.0 PPB   SO2 =XXX.X

< TST TST > **ENTR** SPAN CONC   **EXIT**

> Press **ENTR to** change the **OFFSET** & **SLOPE** values for the SO$_2$ measurements.
> Press **EXIT** to leave the calibration unchanged and return to the previous menu.

M-P CAL   RANGE = 500.0 PPB   SO2 =XXX.X

< TST TST > ENTR   CONC   **EXIT**

> **EXIT** returns to the main **SAMPLE** display

Figure 9-3: Setup for Manual Calibration without Z/S valve or IZS Option (Step 3)

IMPORTANT

IMPACT ON READINGS OR DATA

If the ZERO or SPAN buttons are not displayed during zero or span calibration, the measured concentration value is too different from the expected value and the analyzer does not allow zeroing or spanning the instrument. Refer to Section 12.4 for more information on calibration problems.

9.3. MANUAL CALIBRATION CHECKS

Informal calibration checks will only evaluate the analyzer's response curve, but do not alter it. It is recommended as a regular maintenance item, to perform calibration checks in order to monitor the analyzer's performance. To carry out a calibration check rather than a full calibration, perform the following procedures:

STEP ONE: Connect the sources of zero air and span gas as shown in Figure 9-1.

STEP TWO: Perform the zero/span calibration check procedure:
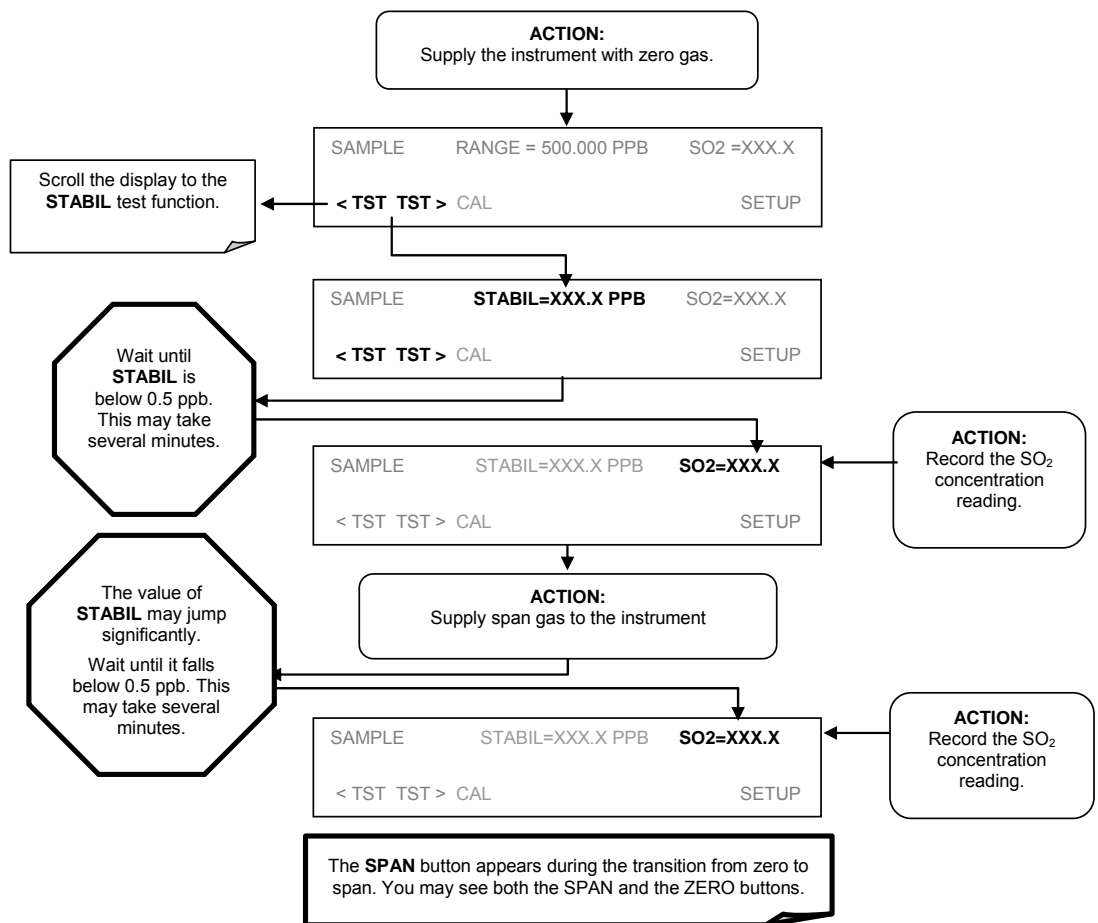
Figure 9-4: Setup for Manual Calibration Checks

9.4. MANUAL CALIBRATION WITH ZERO/SPAN VALVES

Zero and Span calibrations using the Zero/Span Valve option are similar to that described in Section 7.2, except that:

- Zero air and span gas are supplied to the analyzer through the zero gas and span gas inlets rather than through the sample inlet.

- The zero and cal operations are initiated directly and independently with dedicated buttons (**CALZ** and **CALS**)

STEP ONE: Connect the sources of zero air and span gas to the respective ports on the rear panel (refer to Figure 3-1) as shown below.
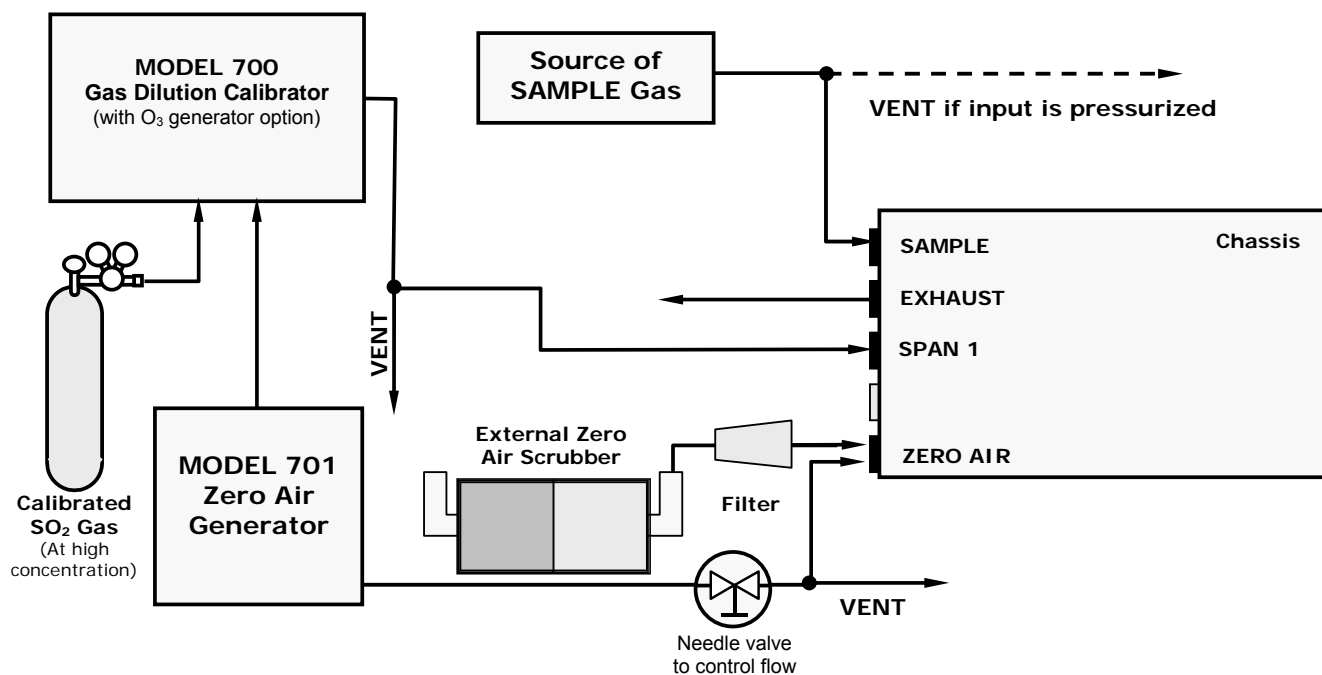
Figure 9-5: Setup for Manual Calibration with Z/S Valve Option Installed (Step 1)

STEP TWO: Set the expected SO_2 span gas value:

The SO_2 span concentration values automatically default to **450.0 Conc**.

To change this value to the actual concentration of the span gas, enter the number by pressing each digit until the expected value appears.

The span gas concentration should always be 90% of the selected reporting range

EXAMPLE
Reporting range = 800 ppb
Span gas conc.= 720 ppb

SAMPLE	RANGE = 500.000 PPB	SO2 =XXX.X
< TST TST > **CAL**		SETUP

This sequence causes the analyzer to prompt for the expected SO_2 span concentration.

M-P CAL	RANGE = 500.000 PPB	SO2 =XXX.X
< TST TST > ZERO	**CONC**	EXIT

M-P CAL	**SO2 SPAN CONC: 450.0 Conc**	
0 0 0 **4** **5** **.0**	**ENTR EXIT**	

EXIT ignores the new setting and returns to the previous display.
ENTR accepts the new setting and returns to the previous display..

Figure 9-6: Setup for Manual Calibration with Z/S Valve Option Installed (Step 2)

Step Three: Perform the calibration or calibration check according to the following flow chart:
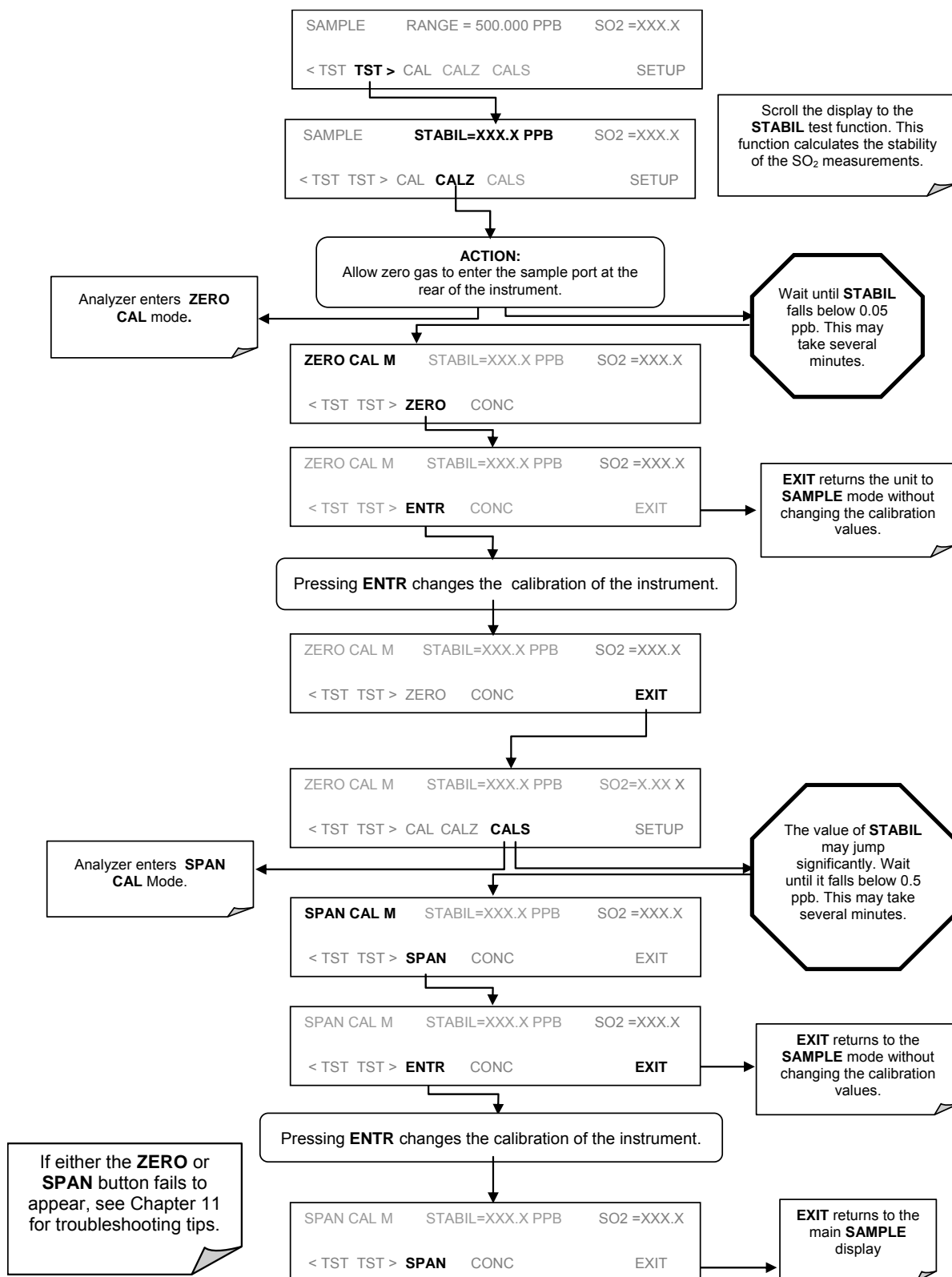
Figure 9-7: Setup for Manual Calibration with Z/S Valve Option Installed (Step 3)

9.5. MANUAL CALIBRATION WITH IZS OPTION

Under the best conditions, the accuracy off the SO_2 effusion rate of the IZS option's permeation tube is about ±5%. This can be subject to significant amounts of drift as the tube ages and the amount of SO_2 contained in the tube is depleted. Whereas this may be sufficient for informal calibration checks, it is not adequate for formal calibrations and is not approved for use by the US EPA as a calibration source.

Therefore, for formal calibrations of an instrument with an IZS option installed the following provisions must be followed.

- Zero air and span gas must be supplied to the analyzer through the sample gas inlet as depicted in Figure 9-1 of Section 9.2.

- The calibration procedure must be initiated using the **CAL** button, not the **CALZ** or **CALS** buttons, using the procedure defined in Section 9.2.

- Using the **CAL** button does not activate the zero/span or sample/cal valves of the IZS option, thus allowing the introduction of zero air and sample gas through the sample port from more accurate, external sources such as a calibrated bottle of SO_2 or a Model T700 Dilution Calibrator.
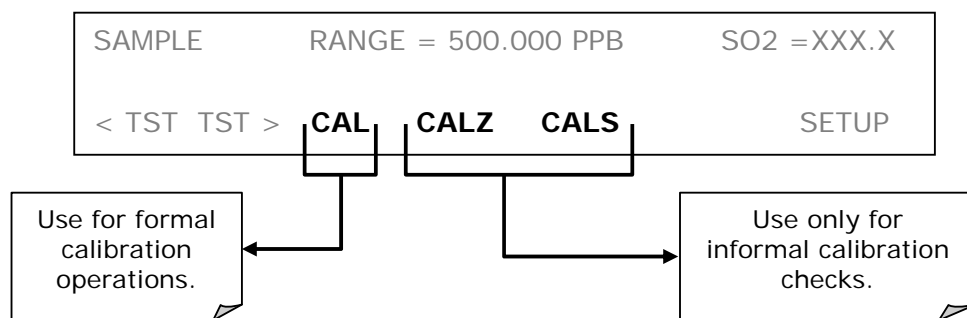
Figure 9-8: Manual Calibration with IZS Option

9.6. MANUAL CALIBRATION CHECKS WITH IZS OR ZERO/SPAN VALVES

Zero and span checks using the zero/span valve or IZS option are similar to that described in Section 9.3, with the following exceptions:

- On units with an IZS option installed, zero air and span gas are supplied to the analyzer through the zero gas inlet and from ambient air.

- On units with a zero/span valve option installed, zero air and span gas are supplied to the analyzer through the zero gas and span gas inlets from two different sources.

- The zero and calibration operations are initiated directly and independently with dedicated buttons CALZ and CALS.

To perform a manual calibration check of an analyzer with a zero/span valve or IZS Option installed, use the following method:

STEP ONE: Connect the sources of Zero Air and Span Gas as shown below.
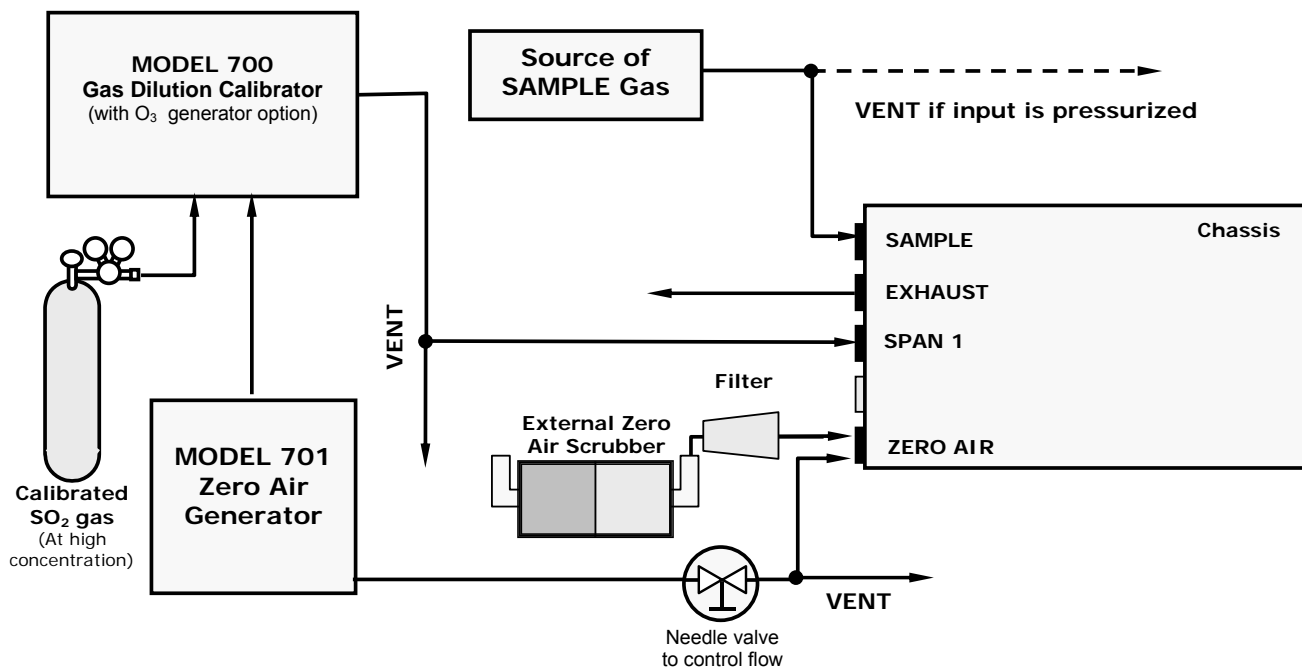
Internal Zero/Span Option (IZS) – Option 51A
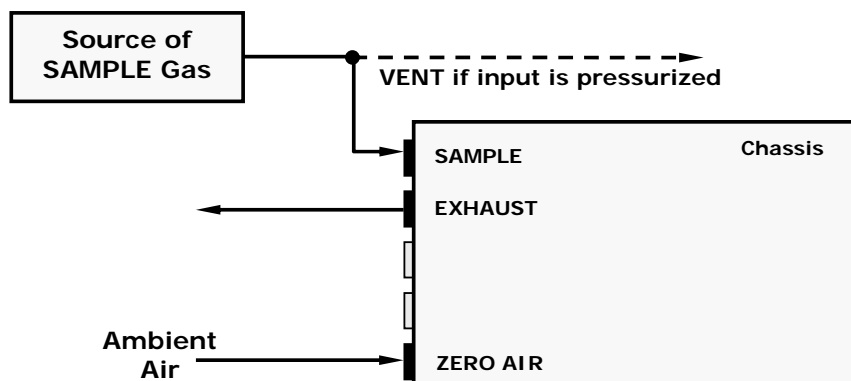
Figure 9-9: Setup for Manual Calibration Check with Z/S Valve or IZS Option (Step 1)

STEP TWO: Perform the zero/span check.
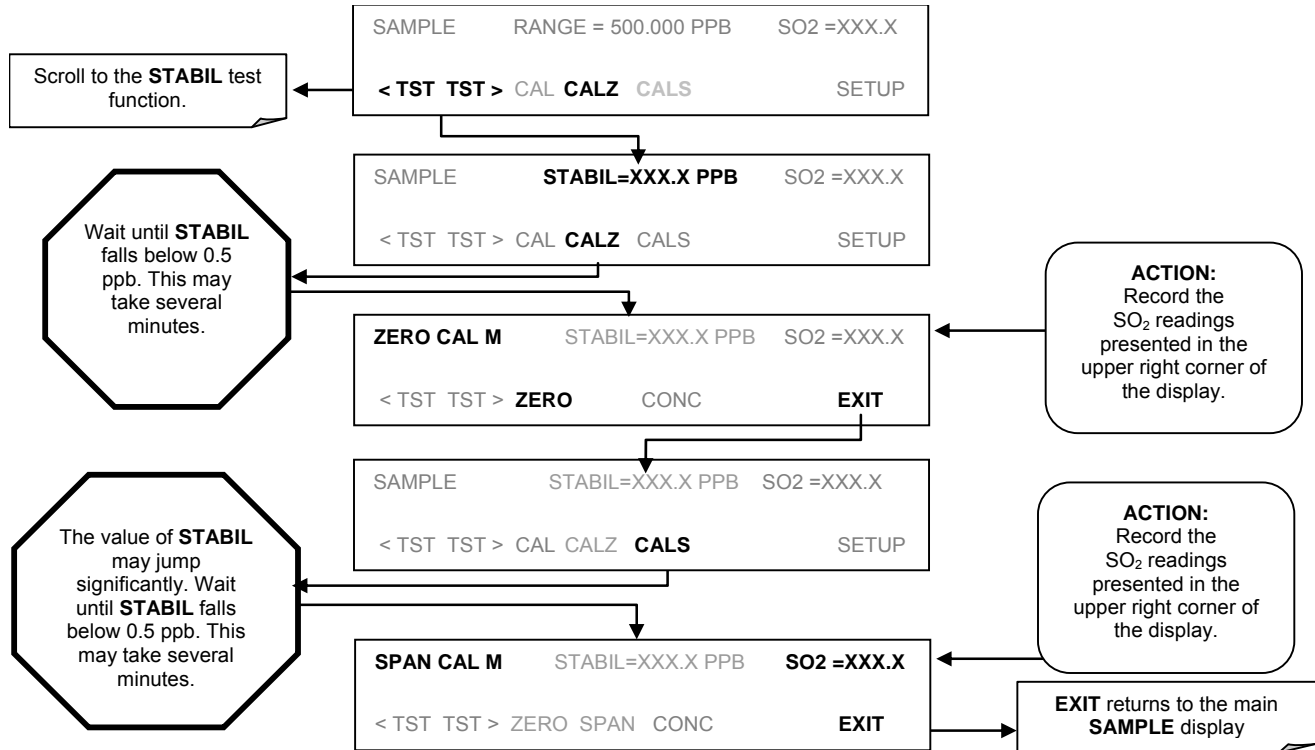
Figure 9-10: Setup for Manual Calibration Check with Z/S Valve or IZS Option (Step 2)

9.7. MANUAL CALIBRATION IN DUAL OR AUTO REPORTING RANGE MODES

When the analyzer is in either Dual or Auto Range modes the user must run a separate calibration procedure for each range. After pressing the **CAL**, **CALZ** or **CALS** buttons the user is prompted for the range that is to be calibrated as seen in the **CALZ** example below:
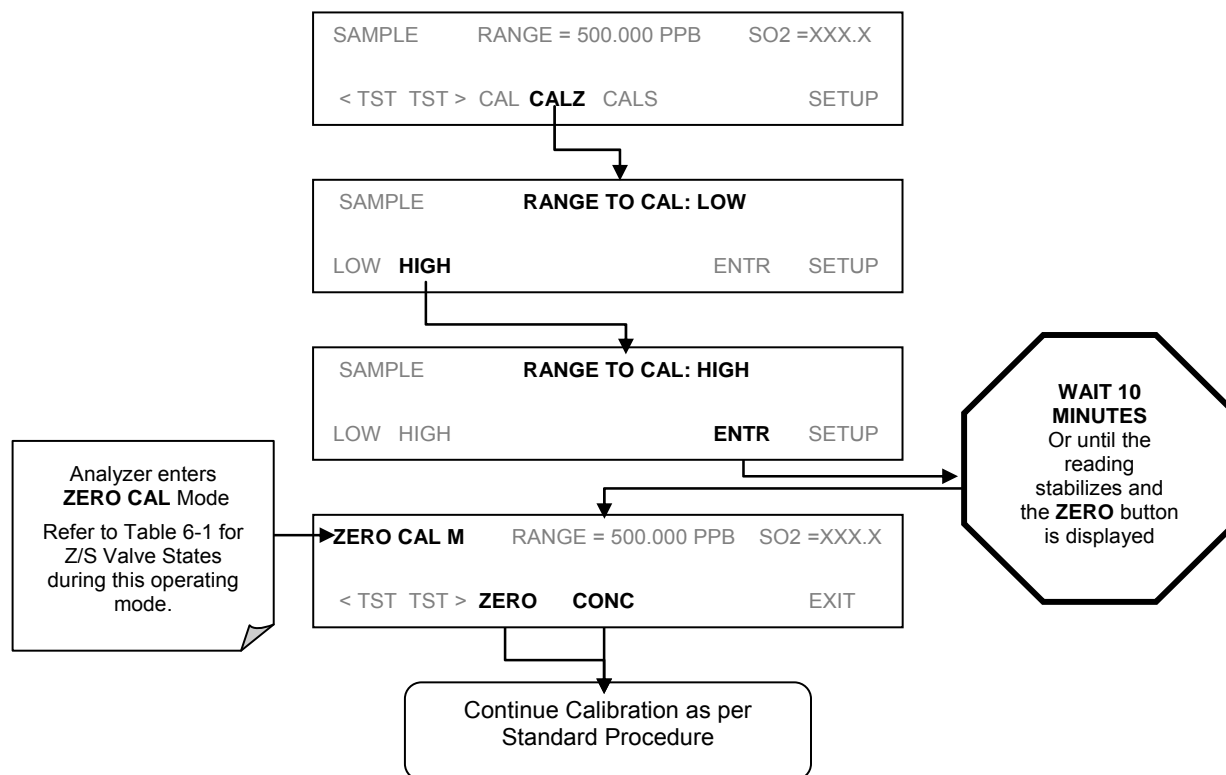
Figure 9-11:   Manual Calibration in Dual/Auto Reporting Range Modes

Once this selection is made, the calibration procedure continues as previously described in Sections 7.2 through 7.6. The other range may be calibrated by starting over from the main **SAMPLE** display.

9.7.1. CALIBRATION WITH REMOTE CONTACT CLOSURES

Contact closures for controlling calibration and calibration checks are located on the rear panel **CONTROL IN** connector. Instructions for setup and use of these contacts can be found in Section 8.1.2.

When the appropriate contacts are closed for at least 5 seconds, the instrument switches into zero, low span or high span mode and the internal zero/span valves will be automatically switched to the appropriate configuration. The remote calibration contact closures may be activated in any order. It is recommended that contact closures remain closed for at least 10 minutes to establish a reliable reading; the instrument will stay in the selected mode for as long as the contacts remain closed.

If contact closures are used in conjunction with the analyzer's AutoCal (refer to Section 9.8) feature and the AutoCal attribute **CALIBRATE** is enabled, the T100 will not re-calibrate the analyzer until the contact is opened. At this point, the new calibration values will be recorded before the instrument returns to SAMPLE mode.

If the AutoCal attribute **CALIBRATE** is disabled, the instrument will return to SAMPLE mode, leaving the instrument's internal calibration variables unchanged.

9.8. AUTOMATIC CALIBRATION (AUTOCAL)

The AutoCal system allows unattended, periodic operation of the zero/span valve options by using the analyzer's internal time of day clock. AutoCal operates by executing user-defined sequences to initiate the various calibration modes of the analyzer and to open and close valves appropriately. It is possible to program and run up to three separate sequences (**SEQ1**, **SEQ2** and **SEQ3**). Each sequence can operate in one of three modes or be disabled.

Table 9-2: AutoCal Modes

MODE	ACTION
DISABLED	Disables the sequence
ZERO	Causes the sequence to perform a zero calibration or check
ZERO-SPAN	Causes the sequence to perform a zero and span concentration calibration or check
SPAN	Causes the sequence to perform a span concentration calibration or check

Each mode has seven setup parameters (Table 9-3) that control operational details of the sequence.

Table 9-3: AutoCal Attribute Setup Parameters

PARAMETER	ACTION
Timer Enabled	Turns on the Sequence timer
Starting Date	Sequence will operate on Starting Date
Starting Time	Sequence will operate at Starting Time[1, 2]
Delta Days	Number of days to skip between each sequence
Delta Time	Incremental delay on each Delta Day that the sequence starts.
Duration	Duration of the sequence in minutes
Calibrate	Enable to do dynamic zero/span calibration, disable to do a cal check only. This must be set to OFF for units used in US EPA applications and with IZS option installed.

[1] The programmed STARTING_TIME must be a minimum of 5 minutes later than the real time clock (refer to Section 6.6 for setting real time clock).

[2] Avoid setting two or more sequences at the same time of the day. Any new sequence which is initiated whether from a timer, the COMM ports, or the contact closure inputs will override any sequence which is in progress.

Note   If at any time an inapplicable entry is selected (Example: Delta Days > 367) the ENTR button will disappear from the display.

Note	**The CALIBRATE attribute must always be set to OFF for analyzers used in US EPA controlled applications that have IZS option installed.**
	Calibration of instruments used in US EPA related applications should only be performed using external sources of zero air and span gas with an accuracy traceable to EPA or NIST standards and supplied through the analyzer's sample port (refer to Section 9.2).

The following example sets Sequence 2 to carry out a zero-span calibration every other day starting at 01:00 on September 4, 2002, lasting 15 minutes. This sequence will start 0.5 hours later each day.

Table 9-4: Example Auto-Cal Sequence

MODE / ATTRIBUTE	VALUE	COMMENT
SEQUENCE	2	Define Sequence #2
MODE	ZERO-SPAN	Select Zero and Span Mode
TIMER ENABLE	ON	Enable the timer
STARTING DATE	Sept. 4, 2002	Start after Sept 4, 2002
STARTING TIME	01:00	First Span starts at 01:00
DELTA DAYS	2	Do Sequence #2 every other day
DELTA TIME	00:30	Do Sequence #2 0.5 h later each day
DURATION	15.0	Operate Span valve for 15 min
CALIBRATE	ON	The instrument will re-set the slope and offset values for the SO_2 channel at the end of the AutoCal sequence

To program the sample sequence shown in Table 9-4:

```
SAMPLE        RANGE = 500.000 PPB      SO2 =XXX.X
< TST TST > CAL CALZ CZLS                    SETUP

SETUP X.X      PRIMARY SETUP MENU
CFG  ACAL  DAS  RNGE  PASS  CLK  MORE  EXIT

SETUP X.X    SEQ 1) DISABLED
             NEXT  MODE                       EXIT

SETUP X.X    SEQ 2) DISABLED
PREV NEXT  MODE                               EXIT

SETUP X.X    MODE: DISABLED
             NEXT                       ENTR EXIT

SETUP X.X    MODE: ZERO
PREV  NEXT                              ENTR EXIT

SETUP X.X    MODE: ZERO–SPAN
PREV  NEXT                              ENTR EXIT

SETUP X.X    SEQ 2) ZERO–SPAN, 1:00:00
PREV NEXT MODE  SET                          EXIT

SETUP X.X    TIMER ENABLE: ON
        SET>  EDIT                           EXIT
```
Default value is ON

```
SETUP X.X    STARTING DATE: 01–JAN–02
        <SET SET>  EDIT                      EXIT
```
Press number buttons to set day, month & year:
Format : DD-MON-YY

```
SETUP X.X    STARTING DATE: 01–JAN–02
    0    4   SEP    0    3   ENTR  EXIT

SETUP X.X    STARTING DATE: 04–SEP–03
    <SET  SET>  EDIT                         EXIT

SETUP C.4    STARTING DATE: 04–SEP–03
    <SET  SET>  EDIT                         EXIT

SETUP C.4    STARTING TIME:00:00
    <SET  SET>  EDIT                         EXIT
```
Press number buttons to set time:
Format : HH:MM

```
SETUP C.4    STARTING TIME:14:15
    <SET  SET>  EDIT                         EXIT

SETUP C.4    DELTA DAYS: 1
    <SET  SET>  EDIT                         EXIT

SETUP C.4   DELTA DAYS: 1
    0    0    2                     ENTR  EXIT

SETUP C.4    DELTA DAYS:2
    <SET  SET>  EDIT                         EXIT
```
Press number buttons to set number of days between procedures (1-367)

```
SETUP C.4    DELTA TIME00:00
    <SET  SET>  EDIT                         EXIT

SETUP C.4    DELTA TIME: 00:00
    0    0    :3    0            ENTR  EXIT

SETUP C.4    DELTA TIEM:00:30
    <SET  SET>  EDIT                         EXIT
```
Press number buttons to set delay time for each iteration of the sequence: HH:MM (0 – 24:00)

```
SETUP C.4    DURATION:15.0 MINUTES
    <SET  SET>  EDIT                         EXIT

SETUP C.4    DURATION 15.0MINUTES
    3    0    .0                   ENTR  EXIT

SETUP C.4    DURATION:30.0 MINUTES
    <SET  SET>  EDIT                         EXIT
```
Press number buttons to set duration for each iteration of the sequence: Set in Decimal minutes from 0.1 – 60.0

```
SETUP C.4    CALIBRATE: OFF
    <SET  SET>  EDIT                         EXIT

SETUP C.4    CALIBRATE: OFF
    ON                            ENTR  EXIT
```
Toggle between Off and ON

```
SETUP C.4    CALIBRATE: ON
    <SET  SET>  EDIT                         EXIT

SETUP C.4    SEQ 2) ZERO–SPAN, 2:00:30
PREV NEXT MODE  SET                           EXIT
```
EXIT returns to the **SETUP** Menu

Figure 9-12:   AUTO CAL – User Defined Sequence

With dynamic calibration turned on, the state of the internal setup variables **DYN_SPAN** and **DYN_ZERO** is set to **ON** and the instrument will reset the slope and offset values for the SO_2 response each time the AutoCal program runs. This continuous re-adjustment of calibration parameters can often mask subtle fault conditions in the analyzer. It is recommended that, if dynamic calibration is enabled, the analyzer's test functions, slope and offset values be checked frequently to assure high quality and accurate data from the instrument.

9.9. CALIBRATION QUALITY

After completing one of the calibration procedures described above, it is important to evaluate the analyzer's calibration **SLOPE** and **OFFSET** parameters. These values describe the linear response curve of the analyzer. The values for these terms, both individually and relative to each other, indicate the quality of the calibration. To perform this quality evaluation, you will need to record the values of both test functions (refer to Section 4.1.1 or Appendix A-3), all of which are automatically stored in the DAS channel **CALDAT** for data analysis, documentation and archival.

Ensure that these parameters are within the limits listed in the following Table.

Table 9-5: Calibration Data Quality Evaluation

FUNCTION	MINIMUM VALUE	OPTIMUM VALUE	MAXIMUM VALUE
SLOPE	-0.700	1.000	1.300
OFFS	50.0 mV	n/a	250.0 mV
These values should not be significantly different from the values recorded on the Teledyne API *Final Test and Validation Data* sheet that was shipped with your instrument. If they are, refer to troubleshooting in Section 12.			

9.10. CALIBRATION OF OPTIONAL SENSORS

This section presents calibration procedures for the O_2 sensor option and for the CO_2 sensor option.

9.10.1. O_2 SENSOR CALIBRATION

Calibration begins with connecting the zero and span gases, then setting the concentration values.

9.10.1.1. O_2 CALIBRATION SETUP

Bottled gases are connected as follows:
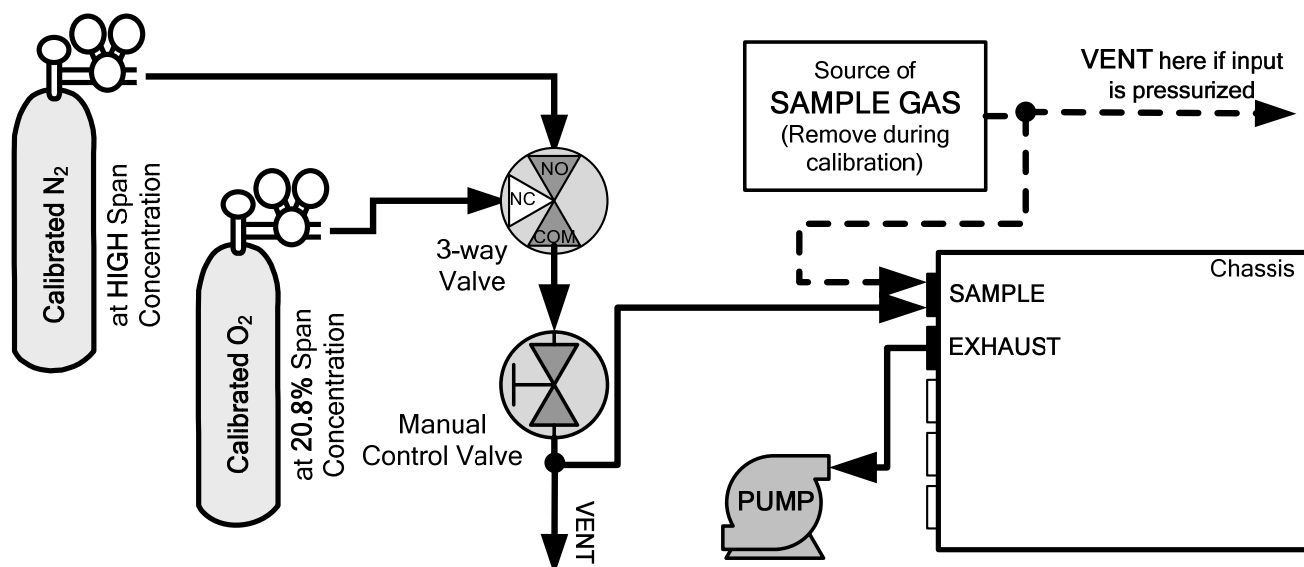
Figure 9-13: O_2 Sensor Calibration Set Up

O_2 **SENSOR ZERO GAS:** Teledyne API recommends using pure N_2 when calibrating the zero point of your O_2 sensor option.

O_2 **SENSOR SPAN GAS:** Teledyne API recommends using 20.9% O_2 in N_2 when calibration the span point of your O_2 sensor.

9.10.1.2. SET O_2 SPAN GAS CONCENTRATION

Set the expected O_2 span gas concentration.

This should be equal to the percent concentration of the O_2 span gas of the selected reporting range (default factory setting = 20.9%; the approximate O_2 content of ambient air).

SAMPLE   RANGE=50.0 PPM   SO2= XX.XX

< TST TST >   **CAL**   SETUP

SAMPLE   **GAS TO CAL:CO**

SO2   CO2   **O2**   ENTR EXIT

SAMPLE   **GAS TO CAL:O2**

SO2   CO2   O2   **ENTR** EXIT

M-P CAL   RANGE=50.0 PPM   SO2= XX.XX

<TST TST> ZERO SPAN **CONC**   EXIT

M-P CAL   O2 SPAN CONC:20.95%

  0   2   0   .9   5   ENTR EXIT

The O$_2$ span concentration value automatically defaults to
20.9 %.
If this is not the the concentration of the span gas being
used, toggle these buttons to set the correct concentration
of the O$_2$ calibration gases.

EXIT ignores the new
setting and returns to
the previous display.
ENTR accepts the new
setting and returns to
the previous menu.

Figure 9-14:   O$_2$ Span Gas Concentration Set Up

9.10.1.3. **ACTIVATE O₂ SENSOR STABILITY FUNCTION**

To change the stability test function from SO$_2$ concentration to the O$_2$ sensor output, press:
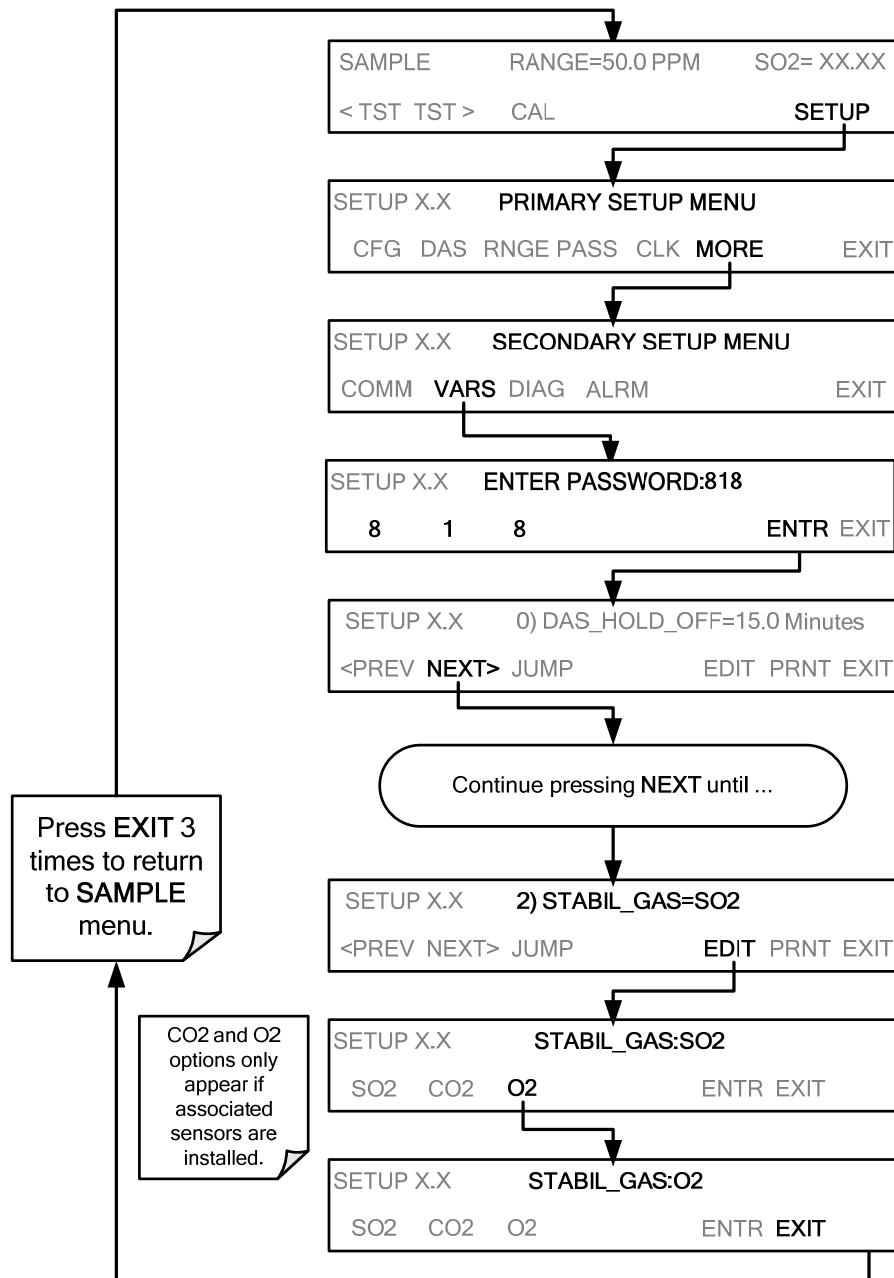
Figure 9-15: **Activate O₂ Sensor Stability Function**

IMPORTANT | **IMPACT ON READINGS OR DATA**

Use the same procedure to reset the STB test function to SO$_2$ when the O$_2$ calibration procedure is complete.

9.10.1.4. O₂ ZERO/SPAN CALIBRATION

To perform the zero/span calibration procedure:
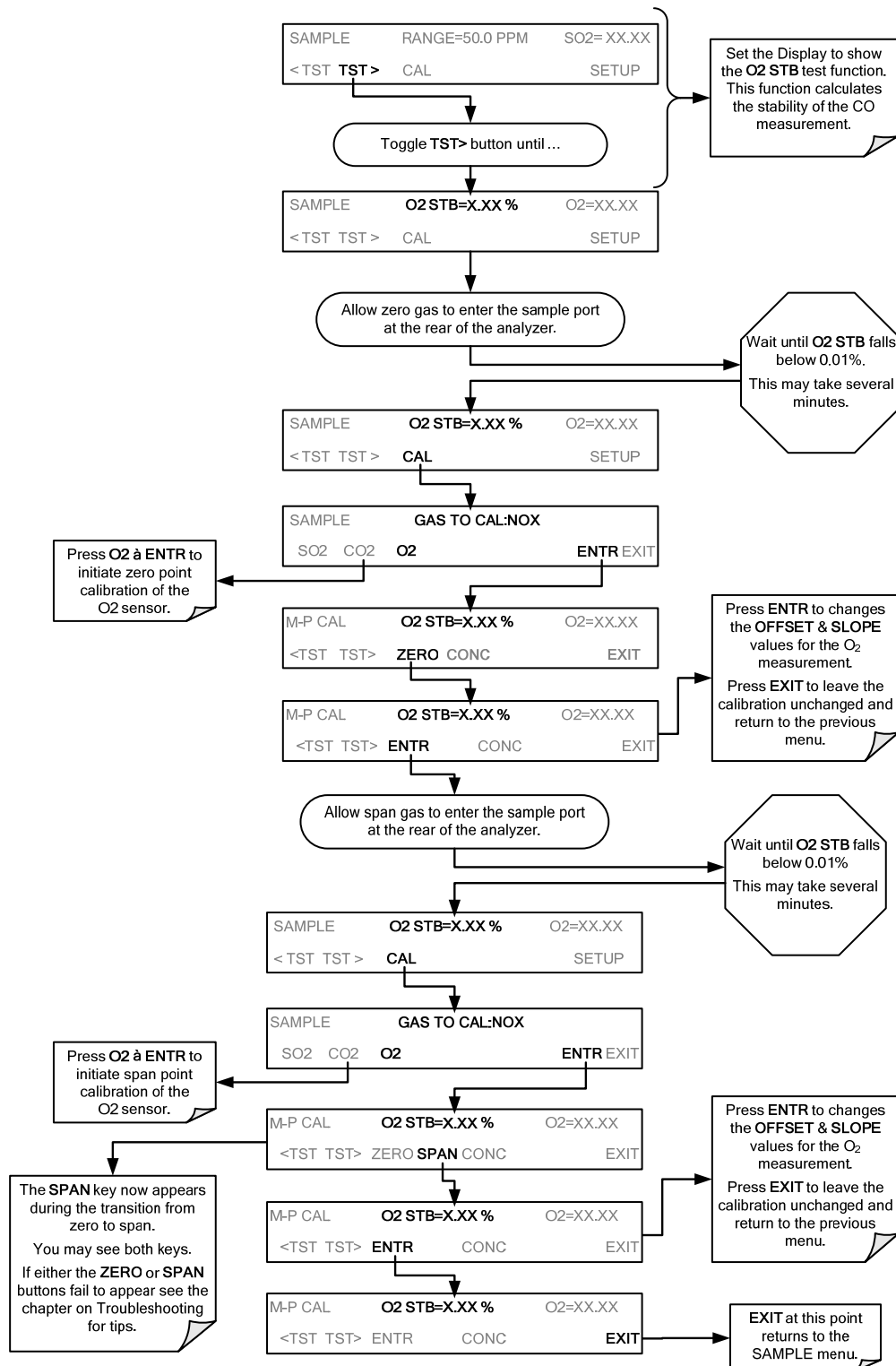
Figure 9-16:   O₂ Zero/Span Calibration

9.10.2. CO$_2$ SENSOR CALIBRATION

Calibration begins with connecting the zero and span gases, then setting the concentration values.

9.10.2.1. CO$_2$ CALIBRATION SETUP

Bottled gases are connected as follows:
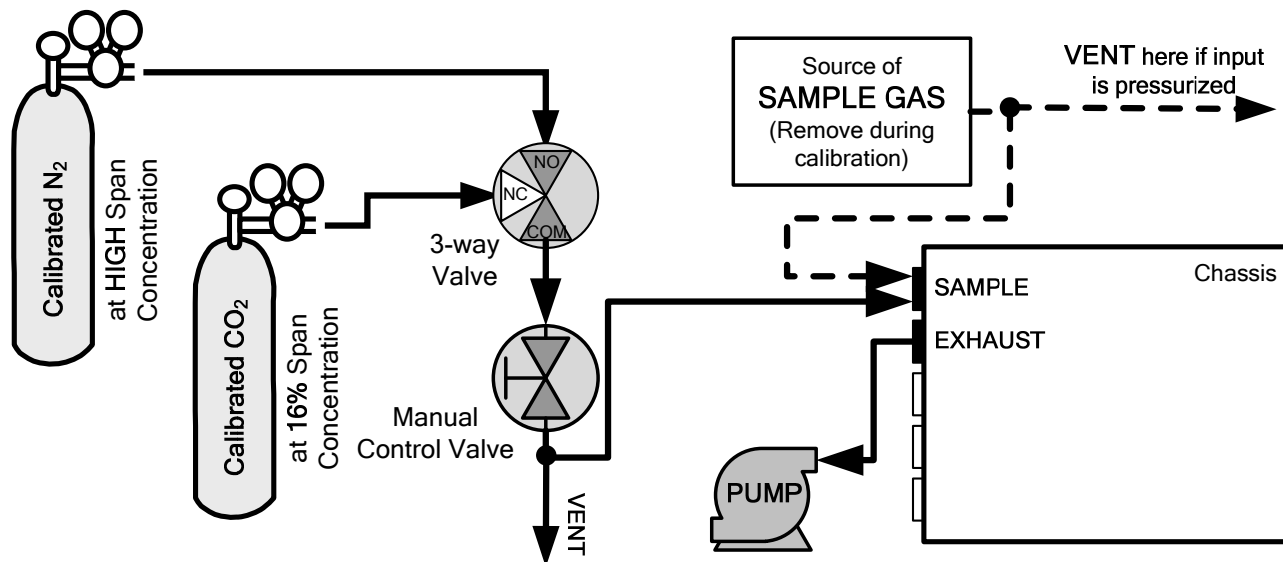
Figure 9-17:   CO$_2$ Sensor Calibration Set Up

CO$_2$ **SENSOR ZERO GAS:** Teledyne API recommends using pure N$_2$ when calibration the zero point of your CO$_2$ sensor option.

CO$_2$ **SENSOR SPAN GAS:** Teledyne API recommends using 16% CO$_2$ in N$_2$ when calibration the span point of your CO$_2$ sensor is 20%.

9.10.2.2. **SET CO$_2$ SPAN GAS CONCENTRATION**

Set the expected CO$_2$ span gas concentration.

This should be equal to the percent concentration of the CO$_2$ span gas of the selected reporting range (default factory setting = 12%).
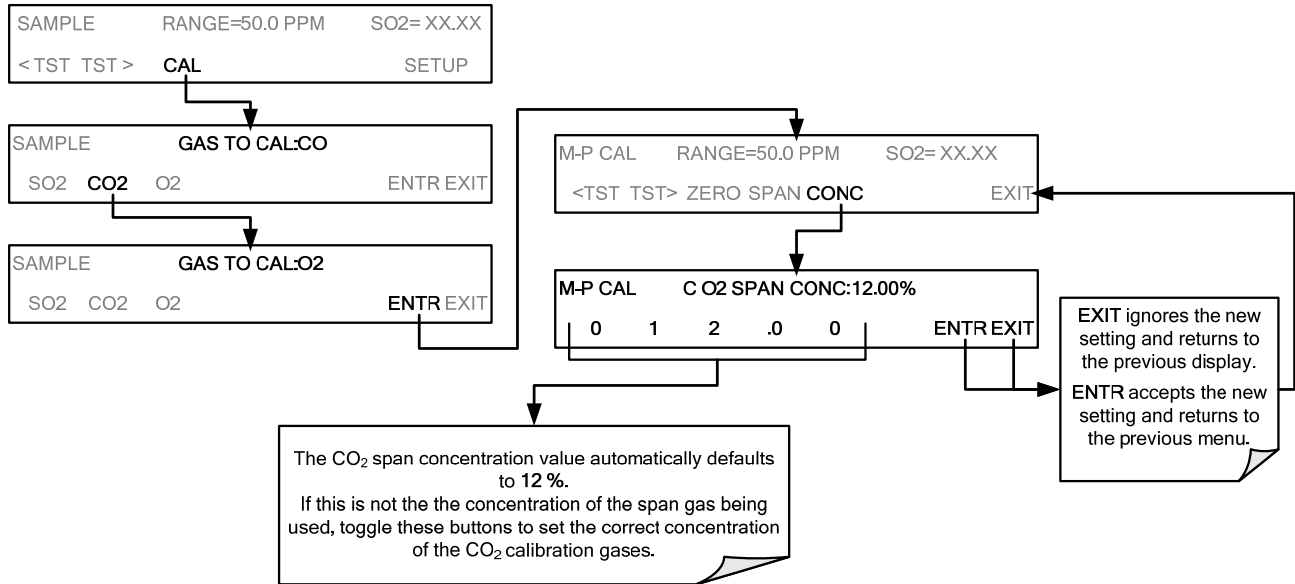
Figure 9-18:   CO$_2$ Span Gas Concentration Setup

9.10.2.3. ACTIVATE CO$_2$ SENSOR STABILITY FUNCTION

To change the stability test function from SO$_2$ concentration to the CO$_2$ sensor output, press:
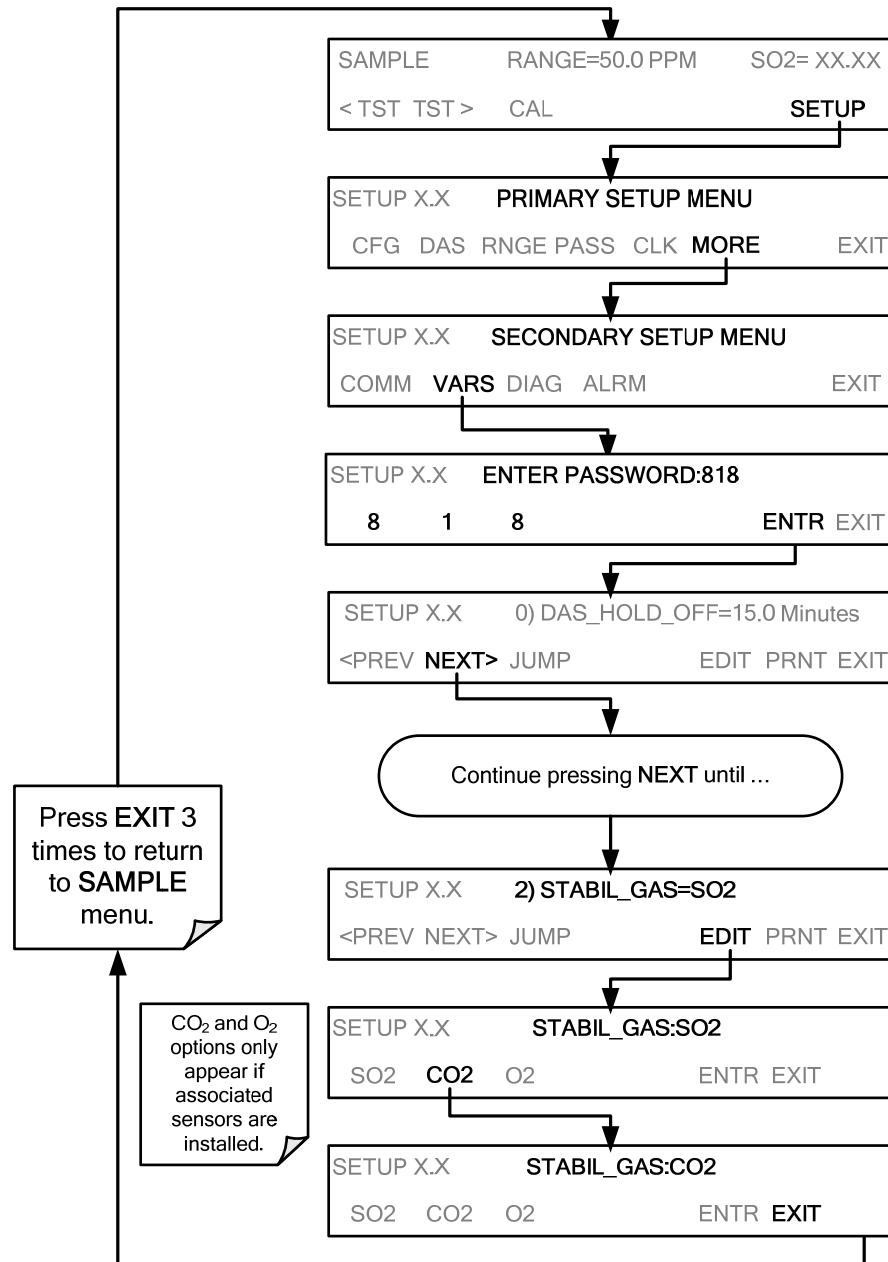
Figure 9-19:   Activate CO$_2$ Sensor Stability Function

IMPORTANT   IMPACT ON READINGS OR DATA

Use the same procedure to reset the STB test function to SO$_2$ when the CO$_2$ calibration procedure is complete.

9.10.2.4. CO₂ ZERO/SPAN CALIBRATION

To perform the zero/span calibration procedure:
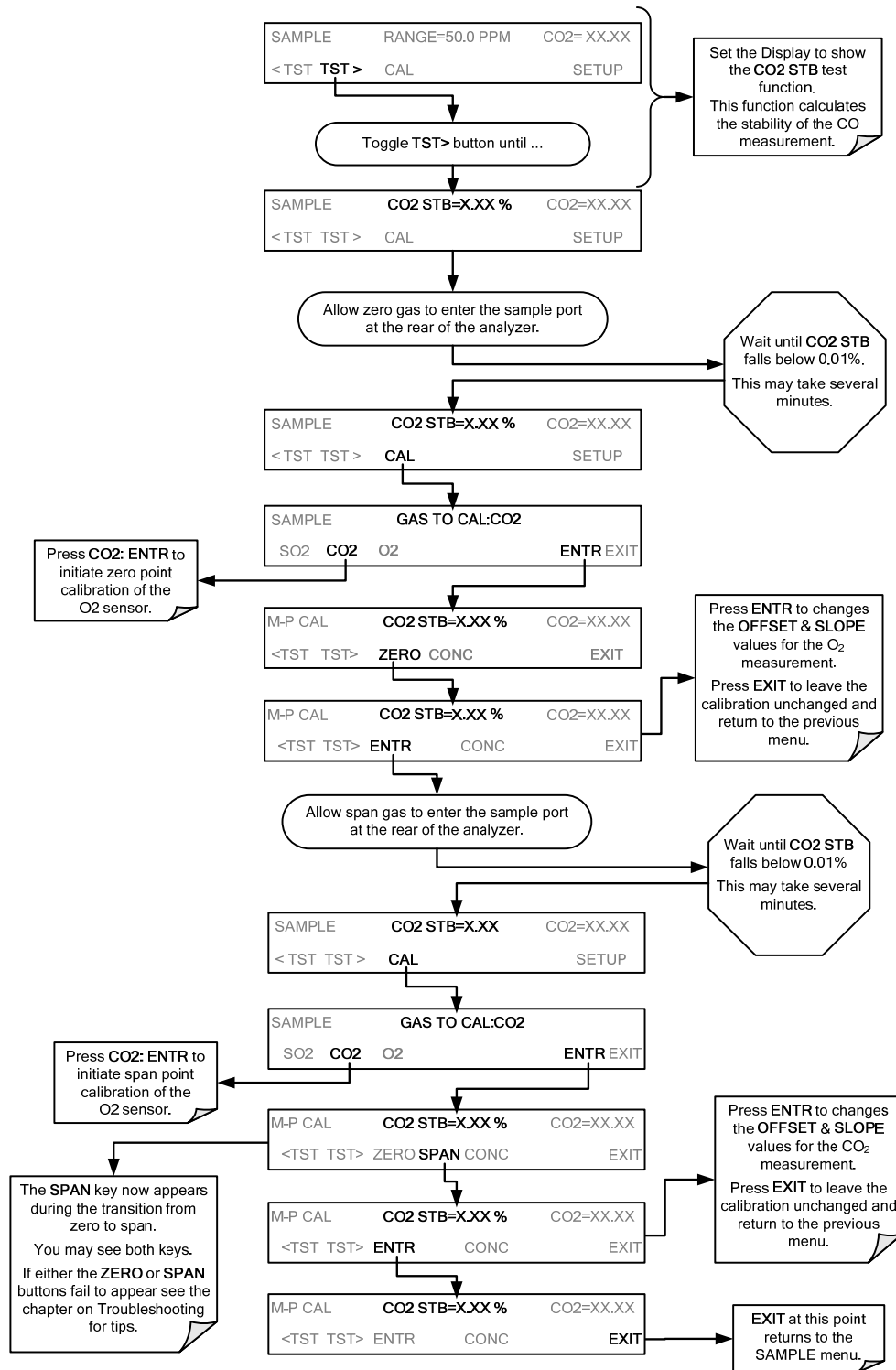
Figure 9-20:   CO₂ Zero/Span Calibration

10. EPA PROTOCOL CALIBRATION

10.1. CALIBRATION REQUIREMENTS

If the T100 is to be used for EPA SLAMS monitoring, it must be calibrated in accordance with the instructions in this section.

In order to insure that high quality, accurate measurements are obtained at all times, the T100 must be calibrated prior to use. A quality assurance program centered on this aspect and including attention to the built-in warning features of the T100 , periodic inspection, regular zero/span checks and routine maintenance is paramount to achieving this.

The US EPA strongly recommends obtaining a copy of the *Quality Assurance Handbook for Air Pollution Measurement Systems, Volume II, Part I* (abbreviated *Q.A. Handbook Volume II*).

Special attention should be paid to Section 2.9 of the EPA handbook which deals with fluorescence based SO_2 analyzers and upon which most of this section is based. Specific regulations regarding the use and operation of ambient sulfur dioxide analyzers can be found in 40 CFR 50 and 40 CFR 58.

10.1.1. CALIBRATION OF EQUIPMENT

In general, calibration is the process of adjusting the gain and offset of the T100 against some recognized standard. The reliability and usefulness of all data derived from any analyzer depends primarily upon its state of calibration. In this section the term *dynamic calibration* is used to express a multipoint check against known standards and involves introducing gas samples of known concentration into the instrument in order to adjust the instrument to a predetermined sensitivity and to produce a calibration relationship. This relationship is derived from the instrumental response to successive samples of different known concentrations. As a minimum, three reference points and a zero point are recommended to define this relationship. The true values of the calibration gas must be traceable to NIST-SRM (refer to Table 9-1).

All monitoring instrument systems are subject to some drift and variation in internal parameters and cannot be expected to maintain accurate calibration over long periods of time. Therefore, it is necessary to dynamically check the calibration relationship on a predetermined schedule. Zero and span checks must be used to document that the data remains within control limits. These checks are also used in data reduction and validation. Table 10-1 summarizes the initial quality assurance activities for calibrating equipment. Table 10-2 is a matrix for the actual dynamic calibration procedure.

Calibrations should be carried out at the field monitoring site. The Analyzer should be in operation for at least several hours (preferably overnight) before calibration so that it is fully warmed up and its operation has stabilized. During the calibration, the T100 should be in the CAL mode, and therefore sample the test atmosphere through all components used during normal ambient sampling and through as much of the ambient air inlet system as is practicable. If the instrument will be used in more than one range (i.e. **DUAL OR AUTO** ranges), it should be calibrated separately on each applicable range. Calibration documentation should be maintained with each analyzer and also in a central backup file.

Table 10-1:   Activity Matrix for Calibration Equipment & Supplies

EQUIPMENT & SUPPLIES	ACCEPTANCE LIMITS	FREQUENCY AND METHOD OF MEASUREMENT	ACTION IF REQUIREMENTS ARE NOT MET
Recorder	Compatible with output signal of analyzer; min. chart width of 150 mm (6 in) is recommended	Check upon receipt	Return equipment to supplier
Sample line and manifold	Constructed of PTFE or glass	Check upon receipt	Return equipment to supplier
Calibration equipment	Meets guidelines of reference 1 and Section 2.3.2 (Q.A. Handbook)	Refer to Section 2.3.9 (Q.A. Handbook)	Return equipment/ supplies to supplier or take corrective action
Working standard SO_2 cylinder gas or SO_2 permeation tube	Traceable to NIST-SRM meets limits in traceability protocol for accuracy and stability (refer to Section 2.0.7, Q.A. Handbook)	Analyzed against NIST-SRM; refer to protocol in Section 2.0.7, Q.A. Handbook	Obtain new working standard and check for traceability
Zero air	Clean dry ambient air, free of contaminants that cause detectable response with the SO_2 analyzer.	Refer to Section 2.9.2 (Q.A. Handbook)	Obtain air from another source or regenerate.
Record form	Develop standard forms	N/A	Revise forms as appropriate
Audit equipment	Must not be the same as used for calibration	System must be checked out against known standards	Locate problem and correct or return to supplier

Table 10-2:   Activity Matrix for Calibration Procedure

EQUIPMENT & SUPPLIES	ACCEPTANCE LIMITS	FREQUENCY AND METHOD OF MEASUREMENT	ACTION IF REQUIREMENTS ARE NOT MET
Calibration gases	NIST traceable	Assayed against an NIST-SRM semi-annually, Sec. 2.0.7, (Q.A. Handbook)	Working gas standard is unstable, and/or measurement method is out of control; take corrective action such as obtaining new calibration gas.
Dilution gas	Zero air, free of contaminants	Refer to Section 2.9.2 (Q.A. Manual)	Return to supplier or take appropriate action with generation system
Multi-point calibration	Use calibration procedure in Subsec. 2.2 (Q.A. Handbook); also <u>Federal Register</u>	Perform at least once every quarter or anytime a level span check indicates a discrepancy, or after maintenance which may affect the calibration; Subsec 2.5 (Q.A. Manual)	Repeat the calibration

10.1.2. DATA RECORDING DEVICE

Either a strip chart recorder, data acquisition system, digital data acquisition system should be used to record the data from the Mode; T100 RS-232 port or analog outputs. If analog readings are being used, the response of that system should be checked against a NIST referenced voltage source or meter. Data recording device should be capable of bipolar operation so that negative readings can be recorded.

10.1.3. RECOMMENDED STANDARDS FOR ESTABLISHING TRACEABILITY

To assure data of desired quality, two considerations are essential: (1) the measurement process must be in statistical control at the time of the measurement and (2) the systematic errors, when combined with the random variation in the measurement process, must result in a suitably small uncertainty.

Evidence of good quality data includes documentation of the quality control checks and the independent audits of the measurement process by recording data on specific forms or on a quality control chart and by using materials, instruments, and measurement procedures that can be traced to appropriate standards of reference. To establish traceability, data must be obtained routinely by repeat measurements of standard reference samples (primary, secondary, and/or working standards). More specifically, working calibration standards must be traceable to standards of higher accuracy, such as those listed in Table 9-1.

Cylinders of working gas traceable to NIST-SRM's (called EPA Protocol Calibration Gas) are also commercially available (from sources such as Scott Specialty Gases, etc.).

10.1.4. EPA CALIBRATION USING PERMEATION TUBES

Teledyne API does not recommend the use of permeation tubes as a source of span gas for EPA protocol calibration operations.

10.1.5. CALIBRATION FREQUENCY

To ensure accurate measurements of the SO_2 concentrations, calibrate the analyzer at the time of installation, and re-calibrate it:

- No later than three months after the most recent calibration or performance audit to indicate an acceptable analyzer calibration.

- An interruption of more than a few days in analyzer operation.

- Any repairs which might affect its calibration.

- Physical relocation of the analyzer.

- Any other indication (including excessive zero or span drift) of possible significant inaccuracy of the analyzer.

Following any of the activities listed above, the zero and span should be checked to determine if a calibration is necessary. If the analyzer zero and span drifts exceed locally established calibration units or the calibration limits in Section 2.0.9, Subsection 9.1.3 (Q.A. Handbook), a calibration should be performed.

10.1.6. RECORD KEEPING

Record keeping is a critical part of all quality assurance programs. Standard forms similar to those that appear in this manual should be developed for individual programs. Three things to consider in the development of record forms are:

- Does the form serve a necessary function?

- Is the documentation complete?

- Will the forms be filed in such a manner that they can easily be retrieved when needed?

10.1.7. SUMMARY OF QUALITY ASSURANCE CHECKS

The following items should be checked on a regularly scheduled basis to assure high quality data from the T100. Refer to Table 10-3 for a summary of activities. Also the QA Handbook should be checked for specific procedures.

Table 10-3:   Activity Matrix for Quality Assurance Checks

CHARACTERISTIC	ACCEPTANCE LIMITS	FREQUENCY AND METHOD OF MEASUREMENT	ACTION IF REQUIREMENTS ARE NOT MET
Shelter temperature	Mean temperature between 22°C and 28°C (72° and 82°F), daily fluctuations not greater than ±2°C	Check thermograph chart weekly for variations greater than ±2°C (4°F)	Mark strip chart for the affected time period Repair or adjust temperature control
Sample introduction system	No moisture, foreign material, leaks, obstructions; sample line connected to manifold	Weekly visual inspection	Clean, repair, or replace as needed
Recorder	Adequate ink & paper Legible ink traces Correct chart speed and range Correct time	Weekly visual inspection	Replenish ink and paper supply Adjust time to agree with clock; note on chart
Analyzer operational settings	TEST measurements at nominal values 2. T100 in SAMPLE mode	Weekly visual inspection	Adjust or repair as needed
Analyzer operational check	Zero and span within tolerance limits as described in Subsec. 9.1.3 of Sec. 2.0.9 (Q.A. Handbook)	Level 1 zero/span every 2 weeks; Level 2 between Level 1 checks at frequency desired analyzer by user	Find source of error and repair After corrective action, re-calibrate analyzer
Precision check	Assess precision as described in Sec. 2.0.8 and Subsec. 3.4.3 (Ibid.)	Every 2 weeks, Subsec. 3.4.3 (Ibid.)	Calc, report precision, Sec. 2.0.8 (Ibid.)

10.2. LEVEL 1 CALIBRATIONS VERSUS LEVEL 2 CHECKS

Essential to quality assurance are scheduled checks for verifying the operational status of the monitoring system. The operator should visit the site at least once each week. It is recommended Level 1 zero and span check conducted on the analyzer every two weeks. Level 2 zero and span checks should be conducted at a frequency desired by the user. Definitions of these terms are given in Table 10-4.

In addition, an independent precision check between 0.08 and 0.10 ppm must be carried out at least once every two weeks. Table 10-3 summarizes the quality assurance activities for routine operations. A discussion of each activity appears in the following sections.

To provide for documentation and accountability of activities, a checklist should be compiled and then filled out by the field operator as each activity is completed.

Table 10-4:   Definition of Level 1 and Level 2 Zero and Span Checks

(Refer to Section 2.0.9 of Q.A. Handbook for Air Pollution Measurement Systems)

LEVEL 1 ZERO AND SPAN CALIBRATION	LEVEL 2 ZERO AND SPAN CHECK
A Level 1 zero and span calibration is a simplified, two-point analyzer calibration used when analyzer linearity does not need to be checked or verified. (Sometimes when no adjustments are made to the analyzer, the Level 1 calibration may be called a zero/span check, in which case it must not be confused with a Level 2 zero/span check.) Since most analyzers have a reliably linear or near-linear output response with concentration, they can be adequately calibrated with only two concentration standards (two-point concentration). Furthermore, one of the standards may be zero concentration, which is relatively easily obtained and need not be certified. Hence, only one certified concentration standard is needed for the two-point (Level 1) zero and span calibration. Although lacking the advantages of the multipoint calibration, the two-point zero and span calibration--because of its simplicity--can be (and should be) carried out much more frequently. Also, two-point calibrations are easily automated. Frequency checks or updating of the calibration relationship with a two-point zero and span calibration improves the quality of the monitoring data by helping to keep the calibration relationship more closely matched to any changes (drifts) in the analyzer response.	A Level 2 zero and span check is an "unofficial" check of an analyzer's response. It may include dynamic checks made with uncertified test concentrations, artificial stimulation of the analyzer's detector, electronic or other types of checks of a portion of the analyzer, etc. Level 2 zero and span checks are <u>not</u> to be used as a basis for analyzer zero or span adjustments, calibration updates, or adjustment of ambient data. They are intended as quick, convenient checks to be used between zero and span calibrations to check for possible analyzer malfunction or calibration drift. Whenever a Level 2 zero or span check indicates a possible calibration problem, a Level 1 zero and span (or multipoint) calibration should be carried out before any corrective action is taken. If a Level 2 zero and span check is to be used in the quality control program, a "reference response" for the check should be obtained immediately following a zero and span (or multipoint) calibration while the analyzer's calibration is accurately known. Subsequent Level 2 check responses should then be compared to the most recent reference response to determine if a change in response has occurred. For automatic Level 2 zero and span checks, the first scheduled check following the calibration should be used for the reference response. It should be kept in mind that any Level 2 check that involves only part of the analyzer's system cannot provide information about the portions of the system not checked and therefore cannot be used as a verification of the overall analyzer calibration.

10.3. ZERO AND SPAN CHECKS

A system of Level 1 and Level 2 zero span checks (refer to Table 10-4) is recommended. These checks must be conducted in accordance with the specific guidance given in the Q.A. Handbook Subsection 9.1 of Section 2.0.9. It is recommended Level 1 zero and span checks conducted every two weeks. Level 2 checks should be conducted in between the Level 1 checks at a frequency desired by the user. Span concentrations for both levels should be between 70 and 90% of the measurement range.

Zero and span data are to be used to:

- Provide data to allow analyzer adjustment for zero and span drift;

- Provide a decision point on when to calibrate the analyzer;

- Provide a decision point on invalidation of monitoring data.

Items 1 and 2 are described in detail in Subsection 9.1.3 of Section 2.0.9 (Q.A. Handbook). Item 3 is described in Subsection 9.1.4 of the same section.

Refer to troubleshooting in Section 12 of this manual if the instrument is not within the allowed variations.

10.3.1. ZERO/SPAN CHECK PROCEDURES

The Zero and Span calibration can be checked a variety of ways. They include:

- **Manual Zero/Span Check** - Zero and Span can be checked via the front panel control buttons. Please refer to Sections 9.3 and 9.6 of this manual.

- **Automatic Zero/Span Checks** - After the appropriate setup, Z/S checks can be performed automatically every night. Refer to Section 9.8 of this manual for setup and operation procedures.

- **Zero/Span checks via remote contact closure** - Zero/Span checks can be initiated via remote contact closures on the rear panel. Refer to Section 9.7.1 of this manual.

- **Zero/Span via RS-232 port** - Z/S checks can be controlled via the RS-232 port. Refer to Section 8 and Appendix A-6 of this manual for more details.

10.4. PRECISION CALIBRATION PROCEDURES AND CHECKS

Calibration must be performed with a calibrator that meets all conditions specified in Subsection 2.9.2 (Q.A. Handbook). The user should be sure that all flow meters are calibrated under the conditions of use against a reliable standard. All volumetric flow rates should be corrected to $25^{o}C$ ($77^{o}F$) and 760mm (29.92in) Hg. Ensure that the calibration system can supply the range of the concentration at a sufficient flow over the whole range of concentration that will be encountered during calibration.

All operational adjustments to the T100 should be completed prior to calibration. The following software features must be set to the desired state before calibration.

- Single range selection. Refer to Section 5.4.3.1 of this manual. If the instrument will be used on more than one range, it should be calibrated separately on each applicable range.

- Automatic temperature/pressure compensation should be enabled. Refer to Section 5.5.

- Alternate units: ensure that the ppb units are selected for EPA monitoring. Refer to Section 5.4.4.

The analyzer should be calibrated on the same range used for monitoring. If the **AUTO** range mode is selected, the highest of the ranges will result in the most accurate calibration, and should be used.

10.4.1. PRECISION CALIBRATION

To perform a precision calibration, the instrument set up; input sources of zero air and sample gas and; procedures should conform to those described in Section 9.2 for analyzers with no valve options or IZS valve option installed and Section 9.5 for analyzers with IZS options installed with the following exception:

10.4.2. PRECISION CHECK

A periodic check is used to assess the data for precision. A one-point precision check must be carried out at least once every 2 weeks on each analyzer at an SO_2 concentration between 0.08 and 0.10 ppm. The analyzer must be operated in its normal sampling mode, and the precision test gas must pass through all filters, scrubbers, conditioners, and other components used during normal ambient sampling. The standards from which precision check test concentrations are obtained must be traceable to NIST-SRM. Those standards used for calibration or auditing may be used.

To perform a precision check, the instrument setup; sources of zero air and sample gas and procedures should conform to those described in Section 9.1.1 for analyzers with no valve options or IZS valve option installed and Section 9.6 for analyzers with Z/S or IZS options installed with the following exception:

Connect the analyzer to a precision gas that has an SO_2 concentration between 0.08 and 0.10 ppm. If a precision check is made in conjunction with a zero/span check, it must be made prior to any zero or span adjustments.

Record this value. Information from the check procedure is used to assess the precision of the monitoring data; refer to 40 CFR 58 for procedures for calculating and reporting precision.

10.5. DYNAMIC MULTIPOINT SPAN CALIBRATION

Dynamic calibration involves introducing gas samples of known concentrations to an instrument in order to record the instruments performance at a predetermined sensitivity and to derive a calibration relationship. A minimum of three reference points and one zero point uniformly spaced covering 0 to 90 percent of the operating range are recommended to define this relationship.

The analyzer's recorded response is compared with the known concentration to derive the calibration relationship.

To perform a precision check, the instrument set up, sources of zero air and sample gas should conform to those described in Section 9.2.

Follow the procedures described in Section 9.2 for calibrating the zero points.

For each mid point:
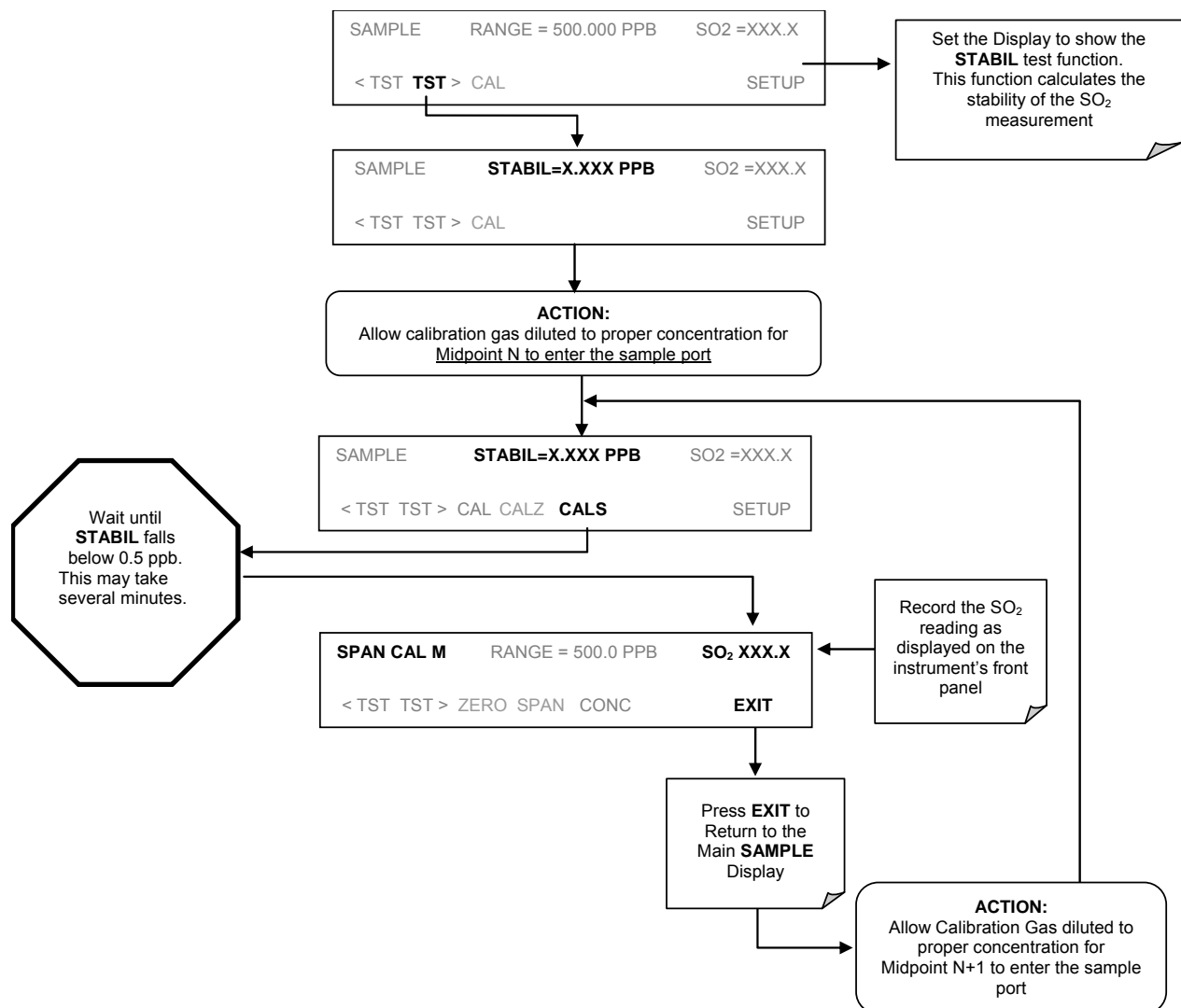
Figure 10-1:   **Dynamic Multipoint Span Calibration**

10.6. SPECIAL CALIBRATION REQUIREMENTS FOR DUAL RANGE OR AUTO RANGE

If Dual Range or Auto Range is selected, then calibration for Range1 and Range2 should be performed separately.

For zero and span point calibration, follow the procedure described in Section 9.2. Repeat the procedure for both the **HIGH** and **LOW** Ranges.

10.7. REFERENCES

1. Environmental Protection Agency, Title 40, Code of Federal Regulations, Part 50, Appendix A, Section 10.3.

2. Quality Assurance Handbook for Air Pollution Measurement Systems - Volume II, Ambient Air Specific Methods, EPA-600/4-77-027a, 1977.

3. Catalog of NBS Standard Reference Materials. NBS Special Publication 260, 1975-76 Edition. U.S. Department of Commerce, NBS. Washington, D.C. June 1975. (Tel: 301-975-6776 for ordering the catalog).

4. Quality Assurance Handbook for Air Pollution Measurement Systems - Volume I, Principles. EPA-600/9-76-005. March 1976.

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PART III

MAINTENANCE AND SERVICE

11. INSTRUMENT MAINTENANCE

Predictive diagnostic functions including data acquisition, failure warnings and alarms built into the analyzer allow the user to determine when repairs are necessary. However, preventive maintenance procedures that, when performed regularly, will help to ensure that the analyzer continues to operate accurately and reliably over its lifetime. Maintenance procedures are covered in this section, followed by troubleshooting and service procedures in Section 12 of this manual.

Note: To support your understanding of the technical details of maintenance, Section 13, *Principles of Operation*, provides information about how the instrument works.

IMPORTANT

IMPACT ON READINGS OR DATA

A span and zero calibration check must be performed following some of the maintenance procedures listed below. Refer to Section 9.

	WARNING! **RISK OF ELECTRICAL SHOCK** **Disconnect power before performing any operations that require entry into the interior of the analyzer.**

	CAUTION **The operations outlined in this section must be performed by qualified maintenance personnel only.**

Note The front panel of the analyzer is hinged at the bottom and may be opened by two fasteners located in the upper right and left corners to gain access to various components that are either mounted on the panel itself or located near the front of the instrument (such as the particulate filter).

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11.1. MAINTENANCE SCHEDULE

Table 11-1 is the recommended maintenance schedule for the T100. Please note that in certain environments with high levels of dust, humidity or pollutant levels some maintenance procedures may need to be performed more often than shown.

Table 11-1:   T100 Preventive Maintenance Schedule

ITEM	ACTION	FREQUENCY	CAL CHECK	MANUAL SECTION	DATE PERFORMED						
[1]Particulate filter	Change particle filter	Weekly	No	11.3.1							
Verify test functions	Review and evaluate	Weekly	No	11.2; Appendix C							
Zero/span check	Evaluate offset and slope	Weekly	--	9.3, 9.6, 9.9							
[1]Zero/span calibration	Zero and span calibration	Every 3 months	--	9.2, 9.4, 9.5, 9.7, 9.8							
[1]External zero air scrubber (optional)	Exchange chemical	Every 3 months	No	11.3.3							
[1]Perform flow check	Check Flow	Every 6 Months	No	11.3.7							
Internal IZS Permeation Tube	Replace	Annually	YES	11.3.2							
Perform pneumatic leak check	Verify Leak Tight	Annually or after repairs involving pneumatics	Yes	11.3.6							
[2]Pump diaphragm	Replace	Annually	Yes	Refer to diaphragm kit instructions							
Calibrate UV Lamp Output	Perform **LAMP CAL**	Prior to zero/span calibration or PMT hardware calibration	--	5.9.6 & 12.7.2.5							
[3]PMT sensor hardware calibration	Low-level hardware calibration	On PMT/ preamp changes if 0.7 < **SLOPE** or **SLOPE >**1.3	Yes	12.7.2.8							
[1]Sample chamber optics	Clean chamber, windows and filters	As necessary	Yes	12.7.2.2 & 12.7.2.3							
[1]Critical flow orifice & sintered filters	Replace	As necessary	Yes	11.3.4							

[1] These Items are required to maintain full warranty; all other items are strongly recommended.
[2] A pump rebuild kit is available from Teledyne API's Technical Support including all instructions and required parts (refer to Appendix B for part numbers).
[3] Replace desiccant bags each time the inspection plate for the sensor assembly is removed.

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11.2. PREDICTIVE DIAGNOSTICS

The analyzer's test functions can be used to predict failures by looking at trends in their values (refer to Table 11-2) and by comparing them values recorded for them at the factory and recorded on the *T100 Final Test and Validation Data Form* (Teledyne API P/N 04551) that was shipped with your analyzer.

A convenient way to record and track changes to these parameters is the internal data acquisition system (DAS). Also, APICOM control software can be used to download and record these data for review even from remote locations (Section 7.3 discusses APICOM).

Table 11-2:   Predictive Uses for Test Functions

TEST FUNCTION	DAS FUNCTION	CONDITION	BEHAVIOR EXPECTED	ACTUAL	INTERPRETATION
PRES	**SMPPRS**	sample gas	Constant within atmospheric changes	Fluctuating	• Developing leak in pneumatic system

				Slowly increasing	• Flow path is clogging up.
					  - Check critical flow orifice & sintered filter.
					  - Replace particulate filter

				Slowly decreasing	• Developing leak in pneumatic system to vacuum (developing valve failure)
DRK PMT	**DRKPMT**	PMT output when UV Lamp shutter closed	Constant within ±20 of check-out value	Significantly increasing	• PMT cooler failure • Shutter Failure
SO₂ Concentration	**CONC1**	At span with IZS option installed	Constant response from day to day	Decreasing over time	• Change in instrument response
					• Degradation of IZS permeation tube
		Standard configuration at span	stable for constant concentration	Decreasing over time	• Drift of instrument response; UV Lamp output is excessively low.

SAMP FL	**SMPFLW**	Standard Operation	Stable	Slowly Decreasing	• Flow path is clogging up.
					  - Check critical flow orifice & sintered filter.
					  - Replace particulate filter

				Fluctuating	• Leak in gas flow path.
LAMP RATIO	**LAMPR**	Standard Operation	Stable and near 100%	Fluctuating or Slowly increasing	• UV detector wearing out • UV source Filter developing pin holes
				Slowly decreasing	• UV detector wearing out • Opaque oxides building up on UV source Filter • UV lamp aging

11.3. MAINTENANCE PROCEDURES

The following procedures need to be performed regularly as part of the standard maintenance of the T100.

11.3.1. CHANGING THE SAMPLE PARTICULATE FILTER

The particulate filter should be inspected often for signs of plugging or excess dirt. It should be replaced according to the service interval in Table 11-1 even without obvious signs of dirt. Filters with 1 and 5 µm pore size can clog up while retaining a clean look. We recommend handling the filter and the wetted surfaces of the filter housing with gloves and tweezers.

IMPORTANT	**IMPACT ON READINGS OR DATA** **Do not touch any part of the housing, filter element, PTFE retaining ring, glass cover and the O-ring with bare hands, as contamination can negatively impact accuracy of readings..**

To change the filter according to the service interval in Table 11-1:

1. Turn OFF the analyzer to prevent drawing debris into the sample line.

2. Open the analyzer's hinged front panel and unscrew the knurled retaining ring of the filter assembly.
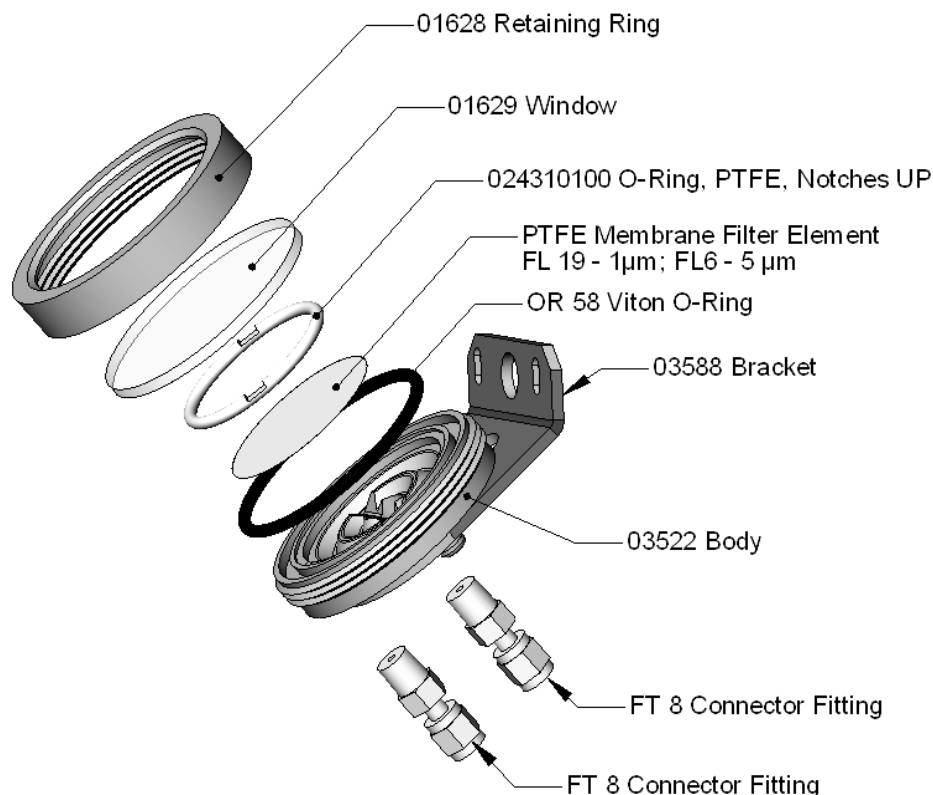
Figure 11-1:   Sample Particulate Filter Assembly

3. Carefully remove the retaining ring, glass window, PTFE O-ring and filter element.

4. Replace the filter element, carefully centering it in the bottom of the holder.

5. Re-install the PTFE O-ring with the notches facing up, the glass cover, then screw on the hold-down ring and hand-tighten the assembly. Inspect the (visible) seal between the edge of the glass window and the O-ring to assure proper gas tightness.

6. Re-start the analyzer.

11.3.2. CHANGING THE IZS PERMEATION TUBE

1. Turn off the analyzer, unplug the power cord and remove the cover.

2. Locate the IZS oven in the rear left of the analyzer.

3. Remove the top layer of insulation if necessary.

4. Unscrew the black aluminum cover of the IZS oven (3 screws) using a medium Phillips-head screw driver. Leave the fittings and tubing connected to the cover.

5. Remove the old permeation tube if necessary and replace it with the new tube. Ensure that the tube is placed into the larger of two holes and that the open permeation end of the tube (Teflon) is facing up.

6. Re-attach the cover with three screws and ensure that the sealing O-ring is properly in place and that the three screws are tightened evenly.

7. Replace the analyzer cover, plug the power cord back in and turn on the analyzer.

8. Carry out an IZS span check to see if the new permeation device works properly. The permeation rate may need several days to stabilize.

ATTENTION

COULD DAMAGE INSTRUMENT AND VOID WARRANTY

Do not leave instrument turned off for more than 8 hours without removing the permeation tube. Do not ship the instrument without removing the permeation tube. The tube continues to emit gas, even at room temperature and will contaminate the entire instrument.

11.3.3. CHANGING THE EXTERNAL ZERO AIR SCRUBBER

The chemicals in the external scrubber need to be replaced periodically according to Table 11-1 or as needed. This procedure can be carried out while the instrument is running. Ensure that the analyzer is not in either the ZERO or SPAN calibration modes.

1. Locate the scrubber on the outside rear panel.

2. Remove the old scrubber by disconnecting the 1/4" plastic tubing from the particle filter using 9/16" and 1/2" wrenches.

3. Remove the particle filter from the cartridge using 9/16" wrenches.

4. Unscrew the top of the scrubber canister and discard charcoal contents. Ensure to abide by local laws for discarding these chemicals. The rebuild kit (listed in

Appendix B) comes with a Material and Safety Data Sheet, which contains more information on these chemicals.

5. Refill the scrubber with charcoal at the bottom.

6. Tighten the cap on the scrubber - hand-tight only.

7. Replace the DFU filter, if required, with a new unit and discard the old.

8. Replace the scrubber assembly into its clips on the rear panel.

9. Reconnect the plastic tubing to the fitting of the particle filter.

10. Adjust the scrubber cartridge such that it does not protrude above or below the analyzer in case the instrument is mounted in a rack. If necessary, squeeze the clips for a tighter grip on the cartridge.

11.3.4. CHANGING THE CRITICAL FLOW ORIFICE

A critical flow orifice, located on the exhaust manifold maintains the proper flow rate of gas through the T100 analyzer. Refer to section 10.3.2.1 for a detailed description of its functionality and location. Despite the fact this device is protected by sintered stainless steel filters, it can, on occasion, clog, particularly if the instrument is operated without a sample filter or in an environment with very fine, sub-micron particle-size dust.

1. Turn off power to the instrument and vacuum pump.

2. Locate the critical flow orifice on the pressure sensor assembly (called out in Figure 11-2).

3. Disconnect the pneumatic line.

4. Unscrew the NPT fitting.
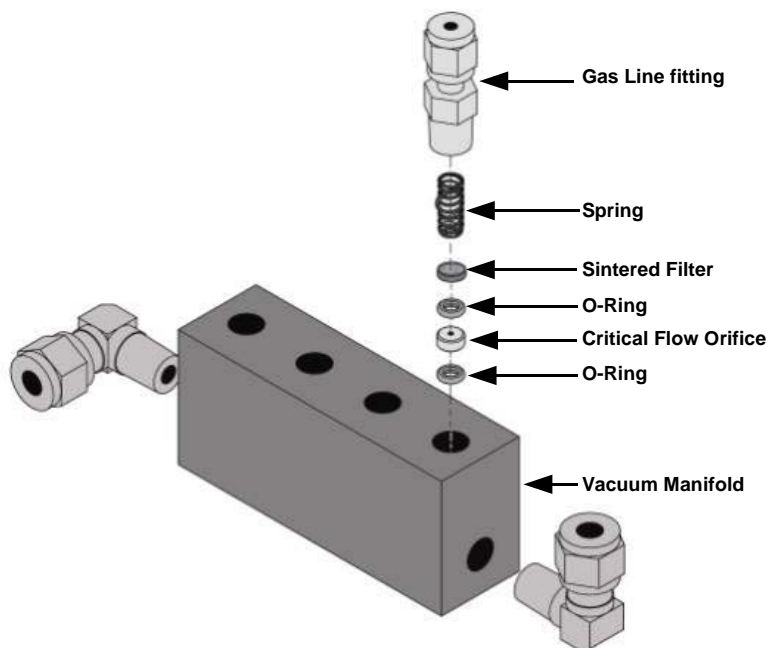
Figure 11-2:   Critical Flow Orifice Assembly

5. Take out the components of the assembly: a spring, a sintered filter, two O-rings and the critical flow orifice.

    You may need to use a scribe or pressure from the vacuum port to get the parts out of the manifold.

6. Discard the two O-rings and the sintered filter.

7. Replace the critical flow orifice.

8. Let the part dry.

9. Re-assemble the parts as shown in Figure 11-2 using a new filter and o-rings.

10. Reinstall the NPT fitting and connect all tubing.

11. Power up the analyzer and allow it to warm up for 60 minutes.

12. Perform a leak check (refer to Section 11.3.6).

11.3.5. CHECKING FOR LIGHT LEAKS

When re-assembled after maintenance, repair or improper operation, the T100 can develop small leaks around the PMT, allowing stray light from the analyzer surroundings into the PMT housing. To find light leaks, follow the below procedures:

CAUTION

This procedure must be carried out by qualified personnel, as it must be performed while the analyzer is powered up and running and its cover removed.

WARNING
RISK OF ELECTRICAL SHOCK

Some operations need to be carried out with the analyzer open and running. Exercise caution to avoid electrical shocks and electrostatic or mechanical damage to the analyzer. Do not drop tools into the analyzer or leave those after your procedures. Do not shorten or touch electric connections with metallic tools while operating inside the analyzer. Use common sense when operating inside a running analyzer.

---

1. Scroll the TEST functions to PMT.

2. Supply zero gas to the analyzer.

3. With the instrument still running, carefully remove the analyzer cover. Take extra care not to touch any of the inside wiring with the metal cover or your body. Do not drop screws or tools into a running analyzer!

4. Shine a powerful flashlight or portable incandescent light at the inlet and outlet fitting and at all of the joints of the sample chamber as well as around the PMT housing. The PMT value should not respond to the light, the PMT signal should remain steady within its usual noise performance.

5. If there is a PMT response to the external light, symmetrically tighten the sample chamber mounting screws or replace the 1/4" vacuum tubing with new, black PTFE tubing (this tubing will fade with time and become transparent). Often, light leaks are also caused by O-rings being left out of the assembly.

6. Carefully replace the analyzer cover.

7. If tubing was changed, carry out a leak check (refer to Section 11.3.6).

11.3.6. DETAILED PRESSURE LEAK CHECK

Obtain a leak checker similar to Teledyne API P/N 01960, which contains a small pump, shut-off valve, and pressure gauge to create both over-pressure and vacuum. Alternatively, a tank of pressurized gas, with the two stage regulator adjusted to ≤ 15 psi, a shutoff valve and pressure gauge may be used.

ATTENTION

COULD DAMAGE INSTRUMENT AND VOID WARRANTY

Once tube fittings have been wetted with soap solution under a pressurized system, do not apply or re-apply vacuum as this will cause soap solution to be sucked into the instrument, contaminating inside surfaces.

Do not exceed 15 psi when pressurizing the system.

1. Turn OFF power to the instrument and remove the instrument cover.

2. Install a leak checker or a tank of gas (compressed, oil-free air or nitrogen) as described above on the sample inlet at the rear panel.

3. Pressurize the instrument with the leak checker or tank gas, allowing enough time to fully pressurize the instrument through the critical flow orifice.

4. Check each tube connection (fittings, hose clamps) with soap bubble solution, looking for fine bubbles.

5. Once the fittings have been wetted with soap solution, do not re-apply vacuum as it will draw soap solution into the instrument and contaminate it.

6. Do not exceed 15 psi pressure.

7. If the instrument has the zero and span valve option, the normally closed ports on each valve should also be separately checked. Connect the leak checker to the normally closed ports and check with soap bubble solution.

8. If the analyzer is equipped with an IZS Option, connect the leak checker to the Dry Air inlet and check with soap bubble solution.

9. Once the leak has been located and repaired, the leak-down rate of the indicated pressure should be less than 1 in-Hg-A (0.4 psi) in 5 minutes after the pressure is turned off.

10. Clean soap solution from all surfaces, re-connect the sample and exhaust lines and replace the instrument cover. Restart the analyzer.

11.3.7. PERFORMING A SAMPLE FLOW CHECK

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IMPACT ON READINGS OR DATA
Use a separate, calibrated flow meter capable of measuring flows between 0 and 1000 cm³/min to measure the gas flow rate though the analyzer. For this procedure, do not refer to the built in flow measurement shown in the front panel display screen.

- -

Sample flow checks are useful for monitoring the actual flow of the instrument, to monitor drift of the internal flow measurement. A decreasing, actual sample flow may point to slowly clogging pneumatic paths, most likely critical flow orifices or sintered filters. To perform a sample flow check:

1. Disconnect the sample inlet tubing from the rear panel SAMPLE port (Figure 3-4).

2. Attach the outlet port of a flow meter to the sample inlet port on the rear panel. Ensure that the inlet to the flow meter is at atmospheric pressure.

3. The sample flow measured with the external flow meter should be 650 cm³/min $\pm$ 10%.

4. Low flows indicate blockage somewhere in the pneumatic pathway. Refer to troubleshooting Section 12.3 for more information on how to fix this.

11.3.8. HYDROCARBON SCRUBBER (*KICKER*)

There are two possible types of problems that can occur with the scrubber: pneumatic leaks and contamination that ruins the inner tube's ability to absorb hydrocarbons.

11.3.8.1. CHECKING THE SCRUBBER FOR LEAKS

Leaks in the outer tubing of the scrubber can be found using the procedure described in Section 11.3.6. Use the following method to determine if a leak exists in the inner tubing of the scrubber.

This procedure requires a pressurized source of air (chemical composition is unimportant) capable of supplying up to 15 psiA and a leak checking fixture such as the one illustrated in Figure 11-3.
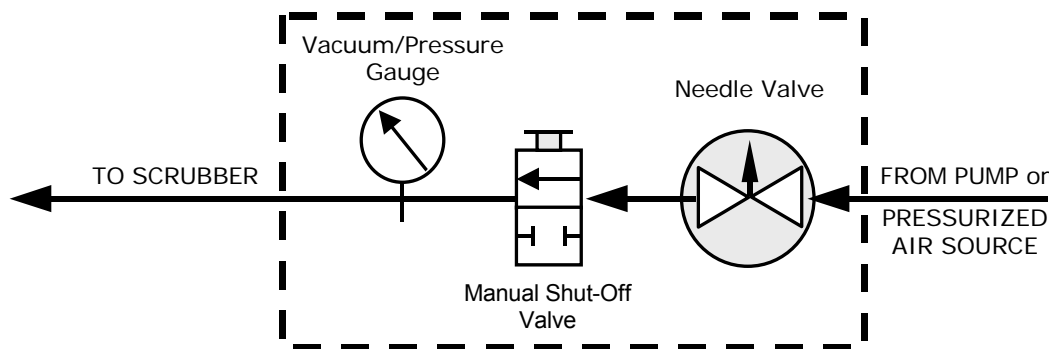
Figure 11-3:   Simple Leak Check Fixture

1. Turn off the analyzer.

2. Disconnect the pneumatic tubing attached to both ends of the scrubber's inner tubing.

3. One end is connected to the sample particulate filter assembly and the other end is connected to the reaction cell assembly.

4. Both ends are made of the 1/8" black Teflon tubing.

5. Cap one end of the hydrocarbon scrubber.

6. Attach the pressurized air source to the other end of the scrubber inner tubing with the leak check fixture in line.
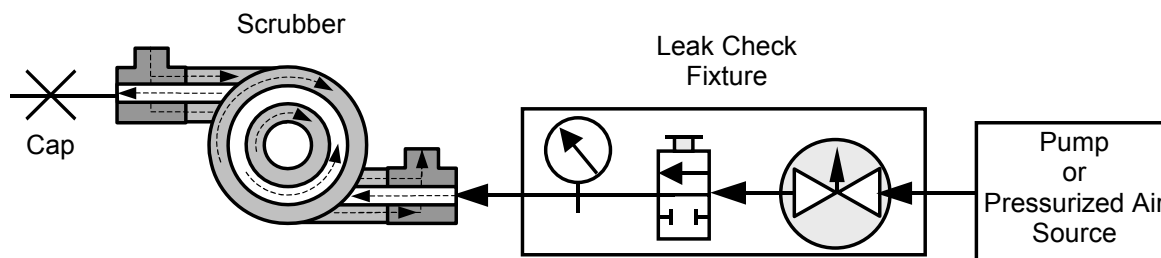
Figure 11-4:   **Hydrocarbon Scrubber Leak Check Setup**

7. Use the needle valve to adjust the air input until the gauge reads 15 psiA.

ATTENTION

COULD DAMAGE INSTRUMENT AND VOID WARRANTY
Do not exceed a pressure of more than 15 psia.

Do not pull the vacuum through the scrubber.

8. Close the shut-off valve.

9. Wait 5 minutes.

If the gauge pressure drops >1 psi within 5 minutes, then the hydrocarbon scrubber has an internal leak and must be replaced. Contact Teledyne API's Technical Support.

12. TROUBLESHOOTING & SERVICE

This section contains a variety of methods for identifying and solving performance problems with the analyzer.

Note:	To support your understanding of the technical details of maintenance, Section 13, *Principles of Operation*, provides information about how the instrument works.

	CAUTION
	THE OPERATIONS OUTLINED IN THIS SECTION MUST BE PERFORMED BY QUALIFIED MAINTENANCE PERSONNEL ONLY.

	WARNING **RISK OF ELECTRICAL SHOCK**
	SOME OPERATIONS NEED TO BE CARRIED OUT WITH THE ANALYZER OPEN AND RUNNING. EXERCISE CAUTION TO AVOID ELECTRICAL SHOCKS AND ELECTROSTATIC OR MECHANICAL DAMAGE TO THE ANALYZER. DO NOT DROP TOOLS INTO THE ANALYZER OR LEAVE THOSE AFTER YOUR PROCEDURES. DO NOT SHORTEN OR TOUCH ELECTRIC CONNECTIONS WITH METALLIC TOOLS WHILE OPERATING INSIDE THE ANALYZER. USE COMMON SENSE WHEN OPERATING INSIDE A RUNNING ANALYZER.

Note	The front panel of the analyzer is hinged at the bottom and may be opened to gain access to various components mounted on the panel itself or located near the front of the instrument (such as the particulate filter).
	Remove the locking screw located at the right-hand side of the front panel.

12.1. GENERAL TROUBLESHOOTING

The T100 has been designed so that problems can be rapidly detected, evaluated and repaired. During operation, it continuously performs diagnostic tests and provides the ability to evaluate its key operating parameters without disturbing monitoring operations.

A systematic approach to troubleshooting will generally consist of the following five steps:

1. Note any **WARNING MESSAGES** and take corrective action as necessary.

2. Examine the values of all TEST functions and compare them to factory values. Note any major deviations from the factory values and take corrective action.

3. Use the internal electronic status LEDs to determine whether the electronic communication channels are operating properly.

- Verify that the DC power supplies are operating properly by checking the voltage test points on the relay PCA.

- Note that the analyzer's DC power wiring is color-coded and these colors match the color of the corresponding test points on the relay PCA.

4. Suspect a leak first!

- Technical Support data indicate that the majority of all problems are eventually traced to leaks in the internal pneumatics of the analyzer or the diluent gas and source gases delivery systems.

- Check for gas flow problems such as clogged or blocked internal/external gas lines, damaged seals, punctured gas lines, a damaged / malfunctioning pumps, etc.

5. Follow the procedures defined in Section 12.6 to confirm that the analyzer's vital functions are working (power supplies, CPU, relay PCA, touch-screen display, PMT cooler, etc.).

- Refer to Figure 3-5 for the general layout of components and sub-assemblies in the analyzer.

- Refer to the wiring interconnect diagram and interconnect list in Appendix D.

12.1.1. FAULT DIAGNOSTICS WITH WARNING MESSAGES

The most common and/or serious instrument failures will result in a warning message displayed on the front panel. Table 12-1 contains a list of warning messages, along with their meaning and recommended corrective action.

It should be noted that if more than two or three warning messages occur at the same time, it is often an indication that some fundamental analyzer sub-system (power supply, relay board, motherboard) has failed rather than an indication of the specific failures referenced by the warnings. In this case, a combined-error analysis needs to be performed.

The analyzer will alert the user that a Warning message is active by flashing the FAULT LED and displaying the Warning message in the Param field along with the **CLR** button (press to clear Warning message). The **MSG** button displays if there is more than one warning in queue or if you are in the TEST menu and have not yet cleared the message. The following display/touchscreen examples provide an illustration of each:

The analyzer also issues a message via the serial port(s).

To view or clear a warning message press:
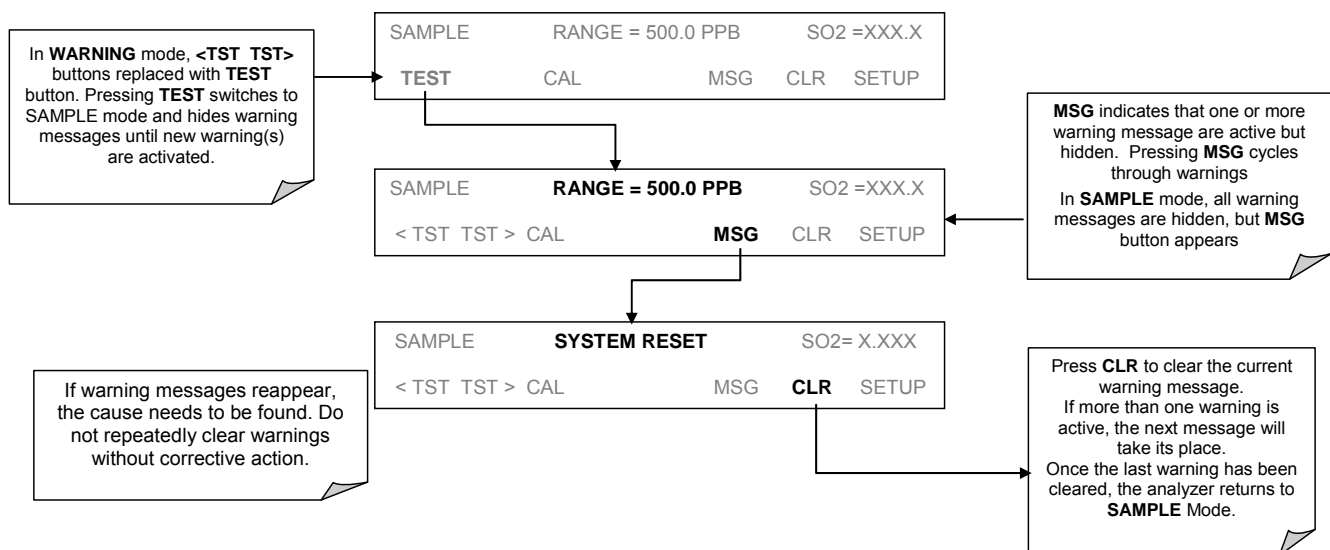
Figure 12-1:   Viewing and Clearing Warning Messages

Table 12-1:   Warning Messages - Indicated Failures

Warning Message	Fault Condition	Possible Causes
ANALOG CAL WARNING	The instruments A/D circuitry or one of its analog outputs is not calibrated	A parameter for one of the analog outputs, even one not currently being used, has been changed and the analog output calibration routine was not re-run A/D circuitry failure on motherboard Other motherboard electronic failure
BOX TEMP WARNING	Box Temp is < 5°C or > 48°C.	NOTE: Box temperature typically runs ~7°c warmer than ambient temperature. Poor/blocked ventilation to the analyzer. Stopped exhaust-fan Ambient temperature outside of specified range
CANNOT DYN SPAN	Dynamic Span operation failed	Measured concentration value is too high or low. Concentration slope value too high or too low
CANNOT DYN ZERO	Dynamic Zero operation failed	Measured concentration value is too high. Concentration offset value too high.
CONFIG INITIALIZED	Configuration and Calibration data reset to original Factory state.	Failed disk on module User erased data
DARK CAL WARNING	The Dark Cal signal is higher than 200 mV.	Light leak in reaction cell Shutter solenoid is not functioning Failed relay board I^2C bus failure Loose connector/wiring PMT preamp board bad or out of cal
DATA INITIALIZED	Data Storage in DAS was erased	Failed disk on module User cleared data
HVPS WARNING	High voltage power supply output is <400 V or >900 V	High voltage power supply is bad High voltage power supply is out of cal A/D converter circuitry is bad
IZS TEMP WARNING	On units with IZS options installed: The permeation tube temperature is Sample chamber temperature is < 45°C or > 55°C	Bad IZS heater Bad IZS temperature sensor Bad relay controlling the IZS heater Entire relay board is malfunctioning I^2C bus malfunction Failure of thermistor interface circuitry on motherboard
PMT DET WARNING	PMT detector output is > 4995 mV	Failed PMT Malfunctioning PMR preamp board A/D converter circuitry failure
PMT TEMP WARNING	PMT temperature is < 2°C or > 12°C	Bad PMT thermo-electric cooler Failed PMT TEC driver circuit Bad PMT preamp board Failed PMT temperature sensor Loose wiring between PMT temperature sensor and PMT Preamp board Malfunction of analog sensor input circuitry on motherboard
RCELL TEMP WARNING	Sample chamber temperature is < 45°C or > 55°C	Bad reaction cell heater Bad reaction cell temperature sensor Bad relay controlling the reaction cell heater Entire relay board is malfunctioning I^2C bus malfunction
REAR BOARD NOT DET	Mother Board not detected on power up.	Warning only appears on serial I/O COMM port(s) Front panel display will be frozen, blank or will not respond. Massive failure of mother board.
SAMPLE FLOW WARN	Sample flow rate is < 500 cc/min or > 1000 cc/min.	Failed sample pump Blocked sample inlet/gas line Dirty particulate filter Leak downstream of critical flow orifice Failed flow sensor/circuitry

SAMPLE PRES WARN	Sample Pressure is <10 in-Hg or > 35 in-Hg[1]	If sample pressure is < 10 in-hg:
		  o Blocked particulate filter
		  o Blocked sample inlet/gas line
		  o Failed pressure sensor/circuitry
		
		If sample pressure is > 35 in-hg:
		  o Blocked vent line on pressurized sample/zero/span gas supply
		  o Bad pressure sensor/circuitry

Warning Message	Fault Condition	Possible Causes

SAMPLE PRES WARN	Sample Pressure is <10 in-Hg or > 35 in-Hg[1]	If sample pressure is < 10 in-hg:
		  o Blocked particulate filter
		  o Blocked sample inlet/gas line
		  o Failed pressure sensor/circuitry
		
		If sample pressure is > 35 in-hg:
		  o Blocked vent line on pressurized sample/zero/span gas supply
		  o Bad pressure sensor/circuitry

SYSTEM RESET	The computer has rebooted.	This message occurs at power on. If it is confirmed that power has not been interrupted: Failed +5 VDC power, Fatal error caused software to restart Loose connector/wiring
UV LAMP WARNING	The UV lamp intensity is < 600mV or > 4995 mV	UV lamp is bad Reference detector is bad or out of adjustment. Mother board analog sensor input circuitry has failed. Fogged or damaged lenses/filters in UV light path A/D converter circuitry failure Light leak in reaction cell Shutter solenoid stuck closed

[1] Normally 29.92 in-Hg at sea level decreasing at 1 in-Hg per 1000 ft of altitude (with no flow – pump disconnected).

IMPORTANT

IMPACT ON READINGS OR DATA

A failure of the analyzer's CPU, motherboard or power supplies can result in any or ALL of the above messages.

12.1.2. FAULT DIAGNOSIS WITH TEST FUNCTIONS

Besides being useful as predictive diagnostic tools, the TEST functions, viewable from the front panel, can be used to isolate and identify many operational problems when combined with a thorough understanding of the analyzer's principles of operation (refer to Section 13. We recommend use of the APICOM remote control program (Section 7) to download, graph and archive TEST data for analysis, and long-term monitoring of diagnostic data.

The acceptable ranges for these test functions are listed in Table A-3 in Appendix A-3. The actual values for these test functions on checkout at the factory were also listed in the *Final Test and Validation Data Sheet*, which was shipped with the instrument. Values outside the acceptable ranges indicate a failure of one or more of the analyzer's subsystems. Functions with values that are within the acceptable range but have significantly changed from the measurements recorded on the factory data sheet may also indicate a failure or a maintenance item.

A problem report worksheet has been provided in Appendix C to assist in recording the value of these test functions. Table 12-2 contains some of the more common causes for these values to be out of range.

IMPORTANT

IMPACT ON READINGS OR DATA

A value of "XXXX" displayed for any of these TEST functions indicates an OUT OF RANGE reading.

Note

Sample Pressure measurements are represented in terms of absolute pressure because this is the least ambiguous method reporting gas pressure.

Absolute atmospheric pressure is about 29.92 in-Hg-A at sea level. It decreases about 1 in-Hg per 1000 ft gain in altitude. A variety of factors such as air conditioning systems, passing storms, and air temperature, can also cause changes in the absolute atmospheric pressure.

Table 12-2:   Test Functions - Possible Causes for Out-Of-Range Values

TEST FUNCTION	NOMINAL VALUE(S)	POSSIBLE CAUSE(S)
STABIL	≤1 ppb with Zero Air	Faults that cause high stability values are: pneumatic leak; low or very unstable UV lamp output; light leak; faulty HVPS; defective preamp board; aging detectors; PMT recently exposed to room light; dirty/contaminated reaction cell.
SAMPLE FL	650 cm^3/min ± 10%	Faults are caused due to: clogged critical flow orifice; pneumatic leak; faulty flow sensor; sample line flow restriction.
PMT	-20 TO 150 mV with Zero Air	High or noisy readings could be due to: calibration error; pneumatic leak; excessive background light; aging UV filter; low UV lamp output; PMT recently exposed to room light; light leak in reaction cell; reaction cell contaminated HVPS problem. *It takes 24-48 hours for the PMT exposed to ambient light levels to adapt to dim light.*
NORM PMT	0-5000 mV, 0-20,000 ppb @ Span Gas Concentration	Noisy Norm PMT value (assuming unchanging SO$_2$ concentration of sample gas): Calibration error; HVPS problem; PMT problem.
UV LAMP SIGNAL	2000 - 4000 mV	This is the instantaneous reading of the UV lamp intensity. Low UV lamp intensity could be due to: aging UV lamp; UV lamp position out of alignment; faulty lamp transformer; aging or faulty UV detector; UV detector needs adjusting; dirty optical components. Intensity lower than 600 mV will cause **UV LAMP WARNING.** Most likely cause is a UV lamp in need of replacement.
LAMP RATIO	30 TO 120%	The current output of the UV reference detector divided by the reading stored in the CPU's memory from the last time a UV Lamp calibration was performed. Out of range lamp ratio could be due to: malfunctioning UV lamp; UV lamp position out of alignment; faulty lamp transformer; aging or faulty UV detector; dirty optical components; pin holes or scratches in the UV optical filters; light leaks.
STR LGT	≤ 100 ppb / Zero Air	High stray light could be caused by: aging UV filter; contaminated reaction cell; light leak; pneumatic leak.
DRK PMT	-50 to +200 mV	High dark PMT reading could be due to: light leak; shutter not closing completely; high pmt temperature; high electronic offset.
DRK LMP	-50 to +200 mV	High dark UV detector could be caused by: light leak; shutter not closing completely; high electronic offset.
HVPS	≈ 400 V to 900 V	Incorrect HVPS reading could be caused by; HVPS broken; preamp board circuit problems.
RCELL TEMP	50ºC ± 1ºC	Incorrect temperature reading could be caused by: malfunctioning heater; relay board communication (I^{2}C bus); relay burnt out
BOX TEMP	Ambient + ≈ 5ºC	Incorrect temperature reading could be caused by: Environment out of temperature operating range; broken thermistor; runaway heater
PMT TEMP	7ºC ± 2ºC Constant	Incorrect temperature reading could be caused by: TEC cooling circuit broken; High chassis temperature; 12V power supply
IZS TEMP (option)	50ºC ± 1ºC	Malfunctioning heater; relay board communication (I^{2}C bus); relay burnt out
PRESS	Ambient ± 2 IN-HG-A	Incorrect sample gas pressure could be due to: pneumatic leak; malfunctioning valve; malfunctioning pump; clogged flow orifices; sample inlet overpressure; faulty pressure sensor
SLOPE	1.0 ± 0.3	Slope out of range could be due to: poor calibration quality; span gas concentration incorrect; leaks; UV Lamp output decay.
OFFSET	< 250 mV	High offset could be due to: incorrect span gas concentration/contaminated zero air/leak; low-level calibration off; light leak; aging UV filter; contaminated reaction cell; pneumatic leak.
TIME OF DAY	Current Time	Incorrect Time could be caused by: Internal clock drifting; move across time zones; daylight savings time?

12.1.3. USING THE DIAGNOSTIC SIGNAL I/O FUNCTIONS

The signal I/O parameters found under the diagnostics (DIAG) menu combined with a thorough understanding of the instrument's principles of operation (refer to Section 13) are useful for troubleshooting in three ways:

- The technician can view the raw, unprocessed signal level of the analyzer's critical inputs and outputs.

- All of the components and functions that are normally under instrument control can be manually changed.

- Analog and digital output signals can be manually controlled.

This allows a user to systematically observe the effect of these functions on the operation of the analyzer. Figure 12-2 shows an example of how to use the signal I/O menu to view the raw voltage of an input signal or to control the state of an output voltage or control signal. The specific parameter will vary depending on the situation. Please note that the analyzer will freeze its concentration output while in the diagnostic signal I/O menu. This is because manually changing I/O outputs can invalidate the instrument reading.

```
┌─────────────────────────────────────────────┐
│ SAMPLE      RANGE = 500.000 PPB    SO2 =XXX.X │
│                                               │
│ < TST  TST > CAL                      SETUP   │
└─────────────────────────────────────────────┘

┌─────────────────────────────────────────────┐
│ SAMPLE      ENTER SETUP PASS : 818            │
│                                               │
│     8    1    8                   ENTR  EXIT  │
└─────────────────────────────────────────────┘

┌─────────────────────────────────────────────┐
│ SETUP X.X     PRIMARY SETUP MENU              │
│                                               │
│ CFG  DAS  RNGE  PASS  CLK  MORE       EXIT    │
└─────────────────────────────────────────────┘

┌─────────────────────────────────────────────┐
│ SETUP X.X     SECONDARY SETUP MENU            │
│                                               │
│ COMM   VARS   DIAG                    EXIT    │
└─────────────────────────────────────────────┘

┌─────────────────────────────────────────────┐
│ DIAG        SIGNAL I/O                         │
│                                               │
│  PREV   NEXT                 ENTR     EXIT    │
└─────────────────────────────────────────────┘

┌─────────────────────────────────────────────┐
│ DIAG  I/O       0 ) EXT_ZERO_CAL=ON           │
│                                               │
│  PREV  NEXT JUMP            PRNT EXIT         │
└─────────────────────────────────────────────┘
```

If parameter is an input signal | If parameter is an output signal or control

```
┌──────────────────────────────────┐   ┌──────────────────────────────────────────┐
│ DIAG  I/O    29) PMT_TEMP=378.3 MV │   │ DIAG I/O    19 ) REACTION CELL_HEATER=ON  │
│                                    │   │                                            │
│  PREV  NEXT JUMP       PRNT EXIT   │   │  PREV  NEXT  JUMP        ON  PRNT EXIT     │
└──────────────────────────────────┘   └──────────────────────────────────────────┘
```

Toggles parameter **ON/OFF**

```
                                        ┌──────────────────────────────────────────┐
                                        │ DIAG I/O    19 ) REACTION CELL_HEATER=OFF │
                                        │                                            │
                                        │  PREV  NEXT  JUMP       OFF  PRNT EXIT     │
                                        └──────────────────────────────────────────┘
```

Exit returns to DIAG display & all values return to software control

Figure 12-2:   Example of Signal I/O Function

12.2. STATUS LEDS

Several color-coded, light-emitting diodes (LEDs) are located inside the instrument to determine if the analyzer's CPU, I^2C communications bus and relay board are functioning properly.

12.2.1. MOTHERBOARD STATUS INDICATOR (WATCHDOG)

DS5, a red LED on the upper portion of the motherboard, just to the right of the CPU board, flashes when the CPU is running the main program. After power-up, DS5 should flash on and off about once per second. If characters are written to the front panel display but DS5 does not flash then the program files have become corrupted. Contact Teledyne API's Technical Support department.

If DS5 is not flashing 30 - 60 seconds after a restart and no characters have been written to the front panel display, the firmware may be corrupted or the CPU may be defective. If DS5 is permanently off or permanently on, the CPU board is likely locked up and should the analyzer not respond (either with locked-up or dark front panel), then replace the CPU.
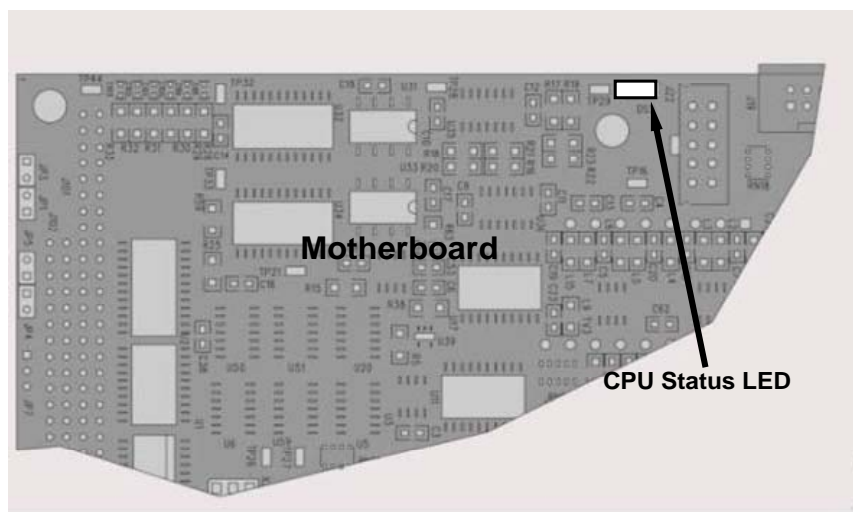
Figure 12-3:   CPU Status Indicator

12.2.2. CPU STATUS INDICATORS

The LEDs on the CPU card (Figure 13-14) are described as follows:

Power LED	Red	normally lit
IDE LED	Green	lit when active (read or write)

12.2.3. RELAY BOARD STATUS LEDS

The most important status LED on the relay board is the red I^2C Bus watch-dog LED, labeled **D1** (or W/D), which indicates the health of the I^2C communications bus. This LED is located in the upper left-hand corner of the relay board when looking at the electronic components. If D1 is blinking, then the other LEDs can be used in conjunction with the **DIAG** menu I/O functions to test hardware functionality by switching devices on and off and watching the corresponding LED turn on or off. The LED only indicates that the logic signal for an output has been activated. If the output driver (i.e. the relay or valve driver IC) is defective, then the LED will light up, but the attached peripheral device will not turn on.

Table 12-3:   Relay Board Status LEDs

LED	COLOR	FUNCTION	FAULT STATUS	INDICATED FAILURE(S)
D1	red	Watchdog Circuit; I^2C bus operation.	Continuously ON or OFF	Failed/Halted CPU Faulty Mother Board, Valve Driver board or Relay PCA Faulty Connectors/Wiring between Motherboard, Valve Driver board or Relay PCA Failed/Faulty +5 VDC Power Supply (PS1)

12.3. GAS FLOW PROBLEMS

The standard analyzer has one main flow path. With the IZS option installed, there is a second flow path through the IZS oven that runs whenever the IZS is on standby to purge SO_2 from the oven chamber. The IZS flow is not measured so there is no reading for it on the front panel display. The full flow diagrams of the standard configuration (refer to Figure 3-18) and with options installed (refer to Figure 3-19 and Figure 3-20) help in troubleshooting flow problems. In general, flow problems can be divided into three categories:

- Flow is too high

- Flow is greater than zero, but is too low, and/or unstable

- Flow is zero (no flow)

When troubleshooting flow problems, it is essential to confirm the actual flow rate without relying on the analyzer's flow display. The use of an independent, external flow meter to perform a flow check as described in Section 12.5.2 is essential.

12.3.1. ZERO OR LOW SAMPLE FLOW

If the pump is operating but the unit reports a **XXXX** gas flow, do the following three steps:

- Check for actual sample flow

- Check pressures

- Carry out a leak check

To check the actual sample flow, disconnect the sample tube from the sample inlet on the rear panel of the instrument. Ensure that the unit is in basic SAMPLE mode. Place a

finger over the inlet and see if it gets sucked in by the vacuum or, more properly, use a flow meter to measure the actual flow. If a proper flow of approximately 650 cm³/min exists, contact Technical Support. If there is no flow or low flow, continue with the next step.

Check that the sample pressure is at or around 28 (or about1 in-Hg-A below ambient atmospheric pressure).

12.3.2. HIGH FLOW

Flows that are significantly higher than the allowed operating range (typically ±10-11% of the nominal flow) should not occur in the M unless a pressurized sample, zero or span gas is supplied to the inlet ports. Be sure to vent excess pressure and flow just before the analyzer inlet ports.

When supplying sample, zero or span gas at ambient pressure, a high flow would indicate that one or more of the critical flow orifices are physically broken (very unlikely case), allowing more than nominal flow, or were replaced with an orifice of wrong specifications. If the flows are more than 15% higher than normal, we recommend that the technician find and correct the cause of the flow problem,

12.4. CALIBRATION PROBLEMS

This section provides information regarding possible causes of various calibration problems.

12.4.1. NEGATIVE CONCENTRATIONS

Negative concentration values may be caused due to the following:

- A slight, negative signal is normal when the analyzer is operating under zero gas and the signal is drifting around the zero calibration point. This is caused by the analyzer's zero noise and may cause reported concentrations to be negative for a few seconds at a time down to -5 ppb, but should alternate with similarly high, positive values.

- Mis-calibration is the most likely explanation for negative concentration values. If the zero air contained some SO_2 gas (contaminated zero air or a worn-out zero air scrubber) and the analyzer was calibrated to that concentration as "zero", the analyzer may report negative values when measuring air that contains little or no SO_2. The same problem occurs, if the analyzer was zero-calibrated using ambient air or span gas.

- If the response offset test function for SO_2 (**OFFSET**) are greater than 150 mV, a failed PMT or high voltage supply, or sample chamber contamination, could be the cause.

12.4.2. NO RESPONSE

If the instrument shows no response (display value is near zero) even though sample gas is supplied properly and the instrument seems to perform correctly,

- Confirm response by supplying SO_2 span gas of about 80% of the range value to the analyzer.

- Check the sample flow rate for proper value.

- Check for disconnected cables to the sensor module.

- Carry out an electrical test with the **ELECTRICAL TEST** (ETEST) procedure in the diagnostics menu, refer to Section 5.9.5. If this test produces a concentration reading, the analyzer's electronic signal path is working.

- Carry out an optical test using the **OPTIC TEST** (OTEST) procedure in the diagnostics menu, refer to Section 5.9.4. If this test results in a concentration signal, then the PMT sensor and the electronic signal path are operating properly. If the M passes both ETEST and OTEST, the instrument is capable of detecting light and processing the signal to produce a reading. Therefore, the problem must be in the pneumatics, optics or the UV lamp/lamp driver.

12.4.3. UNSTABLE ZERO AND SPAN

Leaks in the T100 or in the external gas supply and vacuum systems are the most common source of unstable and non-repeatable concentration readings.

- Check for leaks in the pneumatic systems as described in Section 11.3.6. Consider pneumatic components in the gas delivery system outside the T100 such as a change in zero air source (ambient air leaking into zero air line or a worn-out zero air scrubber) or a change in the span gas concentration due to zero air or ambient air leaking into the span gas line.

- Once the instrument passes a leak check, perform a flow check (refer to Section 11.3.7) to ensure that the instrument is supplied with adequate sample gas.

- Confirm the UV lamp, sample pressure and sample temperature readings are correct and steady.

- Verify that the sample filter element is clean and does not need to be replaced.

12.4.4. INABILITY TO SPAN - NO SPAN BUTTON

In general, the T100 will not display certain control buttons whenever the actual value of a parameter is outside of the expected range for that parameter. If the calibration menu does not show a SPAN button when carrying out a span calibration, the actual concentration must be outside of the range of the expected span gas concentration, which can have several reasons.

- Verify that the expected concentration is set properly to the actual span gas concentration in the **CONC** sub-menu.

- Confirm that the SO_2 span gas source is accurate.

- If you are using bottle calibration gas and have recently changed bottles, bottle to bottle variation may be the cause.

- Check for leaks in the pneumatic systems as described in Section 12.6.1. Leaks can dilute the span gas and, hence, the concentration that the analyzer measures may fall short of the expected concentration defined in the **CONC** sub-menu.

- If the physical, low-level calibration has drifted (changed PMT response) or was accidentally altered by the user, a low-level calibration may be necessary to get the analyzer back into its proper range of expected values. One possible indicator of this scenario is a slope or offset value that is outside of its allowed range (0.7-1.3 for slope, -20 to 150 for offsets). Refer to Section 12.7.2.8 on how to carry out a low-level hardware calibration.

12.4.5. INABILITY TO ZERO - NO ZERO BUTTON

In general, the T100 will not display certain control buttons whenever the actual value of a parameter is outside of the expected range for that parameter. If the calibration menu does not show a ZERO button when carrying out a zero calibration, the actual gas concentration must be significantly different from the actual zero point (as per last calibration), which can have several reasons.

- Confirm that there is a good source of zero air. If the IZS option is installed, compare the zero reading from the IZS zero air source to an external zero air source using SO_2-free air. Check any zero air scrubber for performance and replacement (refer to Section 11.3.3).

- Check to ensure that there is no ambient air leaking into the zero air line. Check for leaks in the pneumatic systems as described in Section 11.3.6.

12.4.6. NON-LINEAR RESPONSE

The T100 was factory calibrated and should be linear to within 1% of full scale. Common causes for non-linearity are:

- Leaks in the pneumatic system. Leaks can add a constant of ambient air, zero air or span gas to the current sample gas stream, which may be changing in concentrations as the linearity test is performed. Check for leaks as described in Section 12.6.

- The calibration device is in error. Check flow rates and concentrations, particularly when using low concentrations. If a mass flow calibrator is used and the flow is less than 10% of the full scale flow on either flow controller, you may need to purchase lower concentration standards.

- The standard gases may be mislabeled as to type or concentration. Labeled concentrations may be outside the certified tolerance.

- The sample delivery system may be contaminated. Check for dirt in the sample lines or sample chamber.

- Calibration gas source may be contaminated.

- Dilution air contains sample or span gas.

- Sample inlet may be contaminated with SO_2 exhaust from this or other analyzers. Verify proper venting of the analyzer's exhaust.

- Span gas overflow is not properly vented and creates a back-pressure on the sample inlet port. Also, if the span gas is not vented at all and does not supply enough sample gas, the analyzer may be evacuating the sample line. Ensure to create and properly vent excess span gas.

- If the instrument is equipped with an internal IZS valve option and the SO_2 span value is continuously trending downward, the IZS permeation tube may require replacement.

12.4.7. DISCREPANCY BETWEEN ANALOG OUTPUT AND DISPLAY

If the concentration reported through the analog outputs does not agree with the value reported on the front panel, you may need to re-calibrate the analog outputs. This becomes more likely when using a low concentration or low analog output range. Analog outputs running at 0.1 V full scale should always be calibrated manually. Refer to Section 5.9.3.3 for a detailed description of this procedure.

12.5. OTHER PERFORMANCE PROBLEMS

Dynamic problems (i.e. problems which only manifest themselves when the analyzer is monitoring sample gas) can be the most difficult and time consuming to isolate and resolve. The following section provides an itemized list of the most common dynamic problems with recommended troubleshooting checks and corrective actions.

12.5.1. EXCESSIVE NOISE

Excessive noise levels under normal operation usually indicate leaks in the sample supply or the analyzer itself. Ensure that the sample or span gas supply is leak-free and carry out a detailed leak check as described earlier in this section.

Another possibility of excessive signal noise may be the preamplifier board, the high voltage power supply and/or the PMT detector itself. Contact the factory on troubleshooting these components.

12.5.2. SLOW RESPONSE

If the analyzer starts responding too slowly to any changes in sample, zero or span gas, check for the following:

- Dirty or plugged sample filter or sample lines.

- Sample inlet line is too long.

- Dirty or plugged critical flow orifices. Check flows, pressures and, if necessary, change orifices (refer to Section 11.3.4).

- Wrong materials in contact with sample - use Teflon materials only.

- Sample vent line is located too far from the instrument sample inlet causing a long mixing and purge time. Locate sample inlet (overflow) vent as close as possible to the analyzer's sample inlet port.

- Dirty sample chamber.

- Insufficient time allowed for purging of lines upstream of the analyzer.

- Insufficient time allowed for SO_2 calibration gas source to become stable.

12.5.3. THE ANALYZER DOESN'T APPEAR ON THE LAN OR INTERNET

Most problems related to Internet communications via the Ethernet card will be due to problems external to the analyzer (e.g. bad network wiring or connections, failed routers, malfunctioning servers, etc.) However, there are several symptoms that indicate the problem may be with the Ethernet card itself.

If neither of the Ethernet cable's two status LED's (located on the back of the cable connector) is lit while the instrument is connected to a network:

- Verify that the instrument is being connected to an active network jack.

- Check the internal cable connection between the Ethernet card and the CPU board.

12.6. SUBSYSTEM CHECKOUT

The preceding sections of this manual discussed a variety of methods for identifying possible sources of failures or performance problems within the analyzer. In most cases this included a list of possible causes and, in some cases, quick solutions or at least a pointer to the appropriate sections describing them. This section describes how to determine if a certain component or subsystem is actually the cause of the problem being investigated.

12.6.1. AC POWER CONFIGURATION

The T100 digital electronic systems will operate with any of the specified power regimes. As long as instrument is connected to 100-120 VAC or 220-240 VAC at either 50 or 60 Hz it will turn on and after about 30 seconds show a front panel display. Internally, the status LEDs located on the Motherboard, the Relay PCA and the CPU should turn on as soon as the power is supplied.

On the other hand, the analyzer's various non-digital components, such as the pump and the AC powered heaters, require that the relay board be properly configured for the type of power being supplied to the instrument.

ATTENTION

COULD DAMAGE INSTRUMENT AND VOID WARRANTY

Plugging the analyzer into a power supply that is too high a voltage or frequency can damage the pump and the AC Heaters.

Plugging the analyzer into a power supply that is too low a voltage or frequency will cause these components to not operate properly.

If the pump and the heaters are not working correctly and incorrect power configuration is suspected, check the serial number label located on the instrument's rear panel (refer to Figure 3-4) to ensure that the instrument was configured for the same voltage and frequency being supplied.

If the information included on the label matches the line voltage, but you still suspect an AC power configuration problem:

For the heaters, check the power configuration jumpers located on the relay board (refer to Figure 12-4).

- If the Jumper block is WHITE the heaters are configured for 115 VAC at 60 Hz.

- If the Jumper block is BLUE the heaters are configured for 220, 240 VAC at 50 Hz.
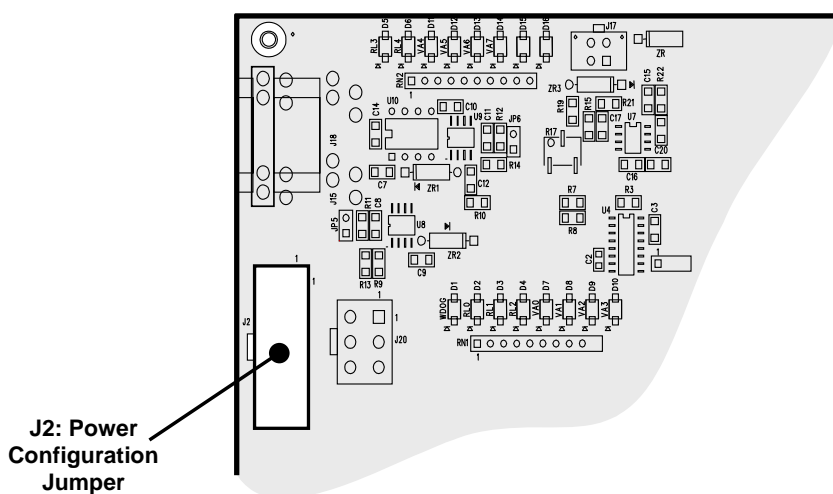
Figure 12-4:   Location of Relay Board Power Configuration Jumper

AC Configuration of the pump is accomplished via an in-line, hard wired, set of connections. Call Teledyne API's Technical Support Department for more information.

12.6.2. DC POWER SUPPLY

If you have determined that the analyzer's AC main power is working, but the unit is still not operating properly, there may be a problem with one of the instrument's switching power supplies, which convert AC power to 5 and ±15 V (PS1) as well as +12 V DC power (PS2). The supplies can either have DC output at all or a noisy output (fluctuating).

To assist tracing DC Power Supply problems, the wiring used to connect the various printed circuit assemblies and DC powered components and the associated test points on the relay board follow a standard color-coding scheme as defined in Table 12-4.

Table 12-4: DC Power Test Point and Wiring Color Code

NAME	TEST POINT#	COLOR	DEFINITION
DGND	1	Black	Digital ground
+5V	2	Red	
AGND	3	Green	Analog ground
+15V	4	Blue	
-15V	5	Yellow	
+12V	6	Purple	
+12R	7	Orange	12 V return (ground) line

A voltmeter should be used to verify that the DC voltages are correct as listed in Table 12-4. An oscilloscope, in AC mode and with band limiting turned on, can be used to evaluate if the supplies are excessively noisy (>100 mV peak-to-peak).

Table 12-5: DC Power Supply Acceptable Levels

POWER SUPPLY	VOLTAGE	CHECK RELAY BOARD TEST POINTS				MIN V	MAX V
		FROM TEST POINT		TO TEST POINT			
		NAME	#	NAME	#		
PS1	+5	DGND	1	+5	2	+4.80	+5.25
PS1	+15	AGND	3	+15	4	+13.5	+16.0
PS1	-15	AGND	3	-15V	5	-14.0	-16.0
PS1	AGND	AGND	3	DGND	1	-0.05	+0.05
PS1	Chassis	DGND	1	Chassis	N/A	-0.05	+0.05
PS2	+12	+12V Ret	6	+12V	7	+11.8	+12.5
PS2	DGND	+12V Ret	6	DGND	1	-0.05	+0.05

12.6.3. I²C BUS

Operation of the I^{2}C bus can be verified by observing the behavior of D1 on the relay PCA & D2 on the Valve Driver PCA . Assuming that the DC power supplies are operating properly, the I^{2}C bus is operating properly if: D1 on the relay PCA and D2 of the Valve Driver PCA are flashing

There is a problem with the I^{2}C bus if both D1 on the relay PCA and D2 of the Valve Driver PCA are ON/OFF constantly.

12.6.4. TOUCH-SCREEN INTERFACE

Verify the functioning of the touch screen by observing the display when pressing a touch-screen control button. Assuming that there are no wiring problems and that the DC power supplies are operating properly, but pressing a control button on the touch screen does not change the display, any of the following may be the problem:

- The touch-screen controller may be malfunctioning.

- The internal USB bus may be malfunctioning.

You can verify this failure by logging on to the instrument using APICOM or a terminal program. If the analyzer responds to remote commands and the display changes accordingly, the touch-screen interface may be faulty.

12.6.5. LCD DISPLAY MODULE

Verify the functioning of the front panel display by observing it when power is applied to the instrument. Assuming that there are no wiring problems and that the DC power supplies are operating properly, the display screen should light and show the splash screen and other indications of its state as the CPU goes through its initialization process.

12.6.6. RELAY BOARD

The relay board circuit can most easily be checked by observing the condition of its status LEDs as described in Section 12.2, and the associated output when toggled on and off through the **SIGNAL I/O** function in the **DIAG** menu, refer to Section 5.9.1.

- If the front panel display responds to button presses and D1 on the relay board is not flashing, then either the I^2C connection between the motherboard and the relay board is bad, or the relay board itself is bad.

- If D1 on the relay board is flashing, but toggling an output in the **Signal I/O** function menu does not toggle the output's status LED, the there is a circuit problem, or possibly a blown driver chip, on the relay board.

- If D1 on the Relay board is flashing and the status indicator for the output in question (heater, valve, etc.) toggles properly using the **Signal I/O** function, but the output device does not turn on/off, then the associated device (valve or heater) or its control device (valve driver, heater relay) is malfunctioning.

Several of the control devices are in sockets and can easily be replaced. The table below lists the control device associated with a particular function:

Table 12-6: Relay Board Control Devices

FUNCTION	CONTROL DEVICE	SOCKETED
Valve0 – Valve3	U5	Yes
Valve4 – Valve7	U6	Yes
All heaters	K1-K5	Yes

12.6.7. MOTHERBOARD

12.6.7.1. **A/D FUNCTIONS**

A basic check of the analog to digital (A/D) converter operation on the motherboard is to use the **Signal I/O** function under the **DIAG** menu. Check the following two A/D reference voltages and input signals that can be easily measured with a voltmeter. Using the **Signal I/O** function (refer to Section 5.9.1 and Appendix D), view the value of **REF_4096_MV** and **REF_GND**.

- The nominal value for **REF_4096_MV** is 4096 mV $\pm$ 10 mV.

- The nominal value for **REF_GND** is 0 mV $\pm$ 3 mV, respectively, of their nominal values (4096 and 0) and are

- If these signals are stable to within ±0.5 mV, the basic A/D converter is functioning properly.

- If these values fluctuate largely or are off by more than specified above, one or more of the analog circuits may be overloaded or the motherboard may be faulty.

- Choose one parameter in the Signal I/O function such as **SAMPLE_PRESSURE** (refer to previous section on how to measure it). Compare its actual voltage with the voltage displayed through the **SIGNAL I/O** function. If the wiring is intact but there is a difference of more than ±10 mV between the measured and displayed voltage, the motherboard may be faulty.

12.6.7.2. **ANALOG OUTPUT VOLTAGES**

To verify that the analog outputs are working properly, connect a voltmeter to the output in question and perform an analog output step test as described in Section 5.9.2.

For each of the steps, taking into account any offset that may have been programmed into the channel (refer to Section 5.9.3.4), the output should be within 1% of the nominal value listed in the Table 11-7 except for the 0% step, which should be within 2-3 mV. If one or more of the steps is outside of this range, a failure of one or both D/A converters and their associated circuitry on the motherboard is likely.

Table 12-7: Analog Output Test Function - Nominal Values

		FULL SCALE OUTPUT VOLTAGE			
		100MV	**1V**	**5V**	**10V***
STEP	**%**	NOMINAL OUTPUT VOLTAGE			
1	0	0 mV	0	0	0
2	20	20 mV	0.2	1	2
3	40	40 mV	0.4	2	4
4	60	60 mV	0.6	3	6
5	80	80 mV	0.8	4	8
6	100	100 mV	1.0	5	10
* Increase the Analog Out (AOUT) Cal Limits in the DIAG>Analog I/O Config menu.					

12.6.7.3. **STATUS OUTPUTS**

The procedure below can be used to test the Status outputs.

1. Connect a cable jumper between the "-" pin and the "▽" pin on the status output connector.

2. Connect a 1000 Ω resistor between the +5 V and the pin for the status output that is being tested.

Table 12-8: Status Outputs Check Pin Out

PIN (left to right)	STATUS
1	System Ok
2	Conc Valid
3	High Range
4	Zero Cal
5	Span Cal
6	Diag Mode
7	Spare
8	Spare

3. Connect a voltmeter between the "-" pin and the pin of the output being tested (refer to Table 12-8).

4. Under the **DIAG → SIGNAL I/O** menu (refer to Section 5.9.1), scroll through the inputs and outputs until you get to the output in question. Alternately turn on and off the output noting the voltage on the voltmeter, it should vary between 0 volts for ON and 5 volts for OFF.

12.6.7.4. **CONTROL INPUTS**

The control input bits can be tested by the following procedure:

1. Connect a jumper from the +5 V pin on the STATUS connector to the U on the CONTROL IN connector.

2. Connect a second jumper from the $\bigtriangledown$ pin on the STATUS connector to the A pin on the CONTROL IN connector. The instrument should switch from **SAMPLE** mode to **ZERO CAL R** mode.

3. Connect a second jumper from the $\bigtriangledown$ pin on the STATUS connector to the B pin on the CONTROL IN connector. The instrument should switch from **SAMPLE** mode to **SPAN CAL R** mode.

In each case, the T100 should return to SAMPLE mode when the jumper is removed.

12.6.8. CPU

There are two major types of CPU board failures, a complete failure and a failure associated with the Disk-On-Module (DOM). If either of these failures occurs, contact the factory.

For complete failures, assuming that the power supplies are operating properly and the wiring is intact, the CPU is faulty if on power-on, the watchdog LED on the motherboard is not flashing.

In some rare circumstances, this failure may be caused by a bad IC on the motherboard, specifically U57, the large, 44 pin device on the lower right hand side of the board. If this is true, removing U57 from its socket will allow the instrument to start up but the measurements will be invalid.

If the analyzer stops during initialization (the front panel display shows a fault or warning message), it is likely that the DOM, the firmware or the configuration and data files have been corrupted.

12.6.9. RS-232 COMMUNICATION

This section provides general RS-232 communication information.

12.6.9.1. **GENERAL RS-232 TROUBLESHOOTING**

Teledyne API's analyzers use the RS-232 protocol as the standard, serial communications protocol. RS-232 is a versatile standard, which has been used for many years but, at times, is difficult to configure. Teledyne API conforms to the standard pin assignments in the implementation of RS-232. Problems with RS-232 connections usually center around 4 general areas:

- Incorrect cabling and connectors. This is the most common problem. Refer to Section 3.3.1.8 for connector, pin-out and setup information.

- The communications (baud) rate and protocol parameters are incorrectly configured. Refer to 3.3.1.8 and 6.2 for baud rate information.

- The COMM port communications mode is set incorrectly (refer to Section 6.2.1).

- If a modem is used, additional configuration and wiring rules must be observed. Refer to Section 8.3.

- Incorrect setting of the DTE - DCE Switch. Refer to Section 6.1.

12.6.9.2. MODEM OR TERMINAL OPERATION

These are the general steps for troubleshooting problems with a modem connected to a Teledyne API analyzer.

- Check cables for proper connection to the modem, terminal or computer.

- Check the correct position of the DTE/DCE switch as described in Section 6.1.

- Check the correct setup command (refer to Section 8.3).

- Verify that the Ready to Send (RTS) signal is at logic high. The T100 sets Pin 7 (RTS) to greater than 3 volts to enable modem transmission.

- Ensure that the baud rate, word length, and stop bit settings between modem and analyzer match (refer to Sections 6.2.2 and 8.3).

- Use the RS-232 test function to send "w" characters to the modem, terminal or computer. Refer to Section 6.2.3.

- Get your terminal, modem or computer to transmit data to the analyzer (holding down the space bar is one way). The green LED on the rear panel should flicker as the instrument is receiving data.

- Ensure that the communications software is functioning properly.

Further help with serial communications is available in a separate manual "RS-232 Manual", Teledyne API's P/N 013500000, available online at http://www.Teledyne-api.com/manuals/.

12.6.10. SHUTTER SYSTEM

To check the functionality of the UV light Shutter by manually activating it:
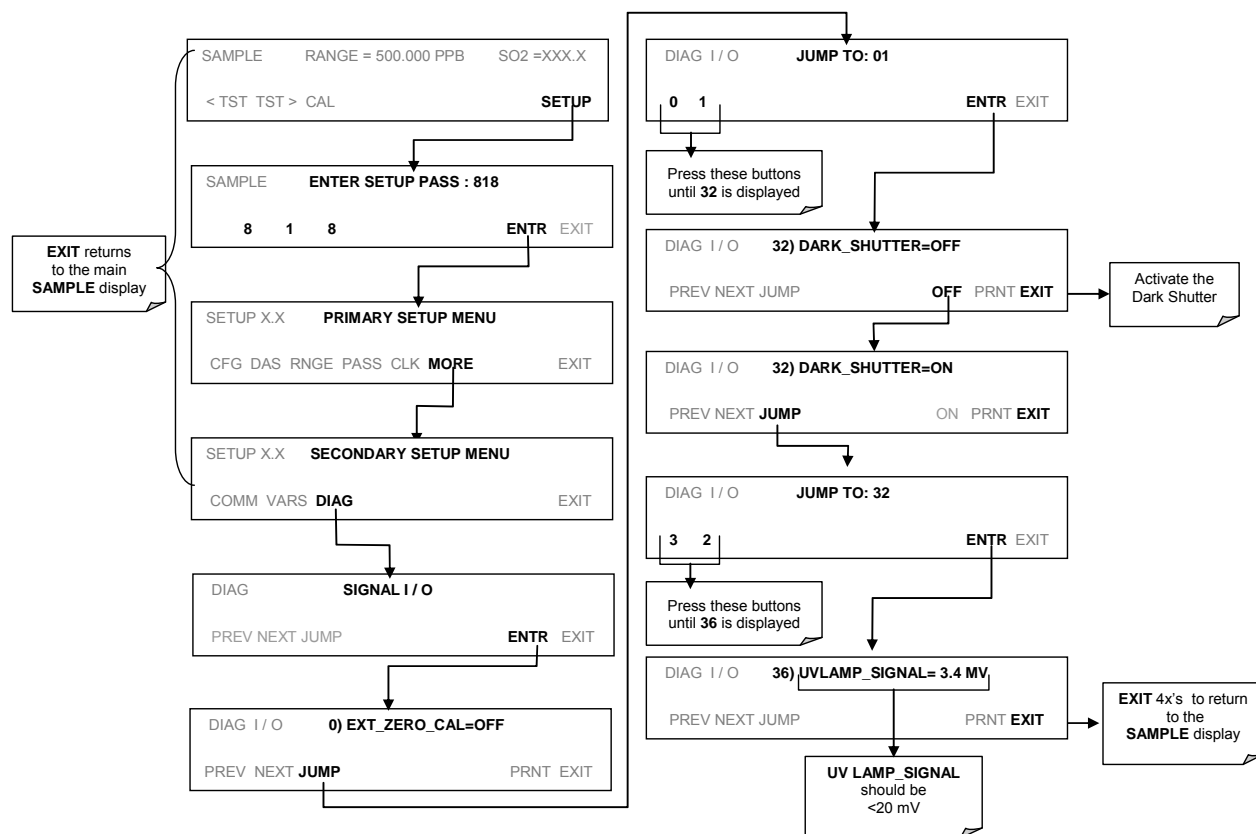
Figure 12-5:   Manual Activation of the UV Light Shutter

12.6.11. PMT SENSOR

The photo multiplier tube detects the light emitted by the UV excited fluorescence of SO_2. It has a gain of about 500000 to 1000000. It is not possible to test the detector outside of the instrument in the field. The best way to determine if the PMT is working properly is by using the optical test (**OTEST**), which is described in Section 5.9.4. The basic method to diagnose a PMT fault is to eliminate the other components using **ETEST**, **OTEST** and specific tests for other sub-assemblies.

12.6.12. PMT PREAMPLIFIER BOARD

To check the correct operation of the preamplifier board, we suggest the technician carry out the electrical and optical tests described in 5.9.4 and 5.9.5.

If the **ETEST** fails, the preamplifier board may be faulty.

12.6.13. PMT TEMPERATURE CONTROL PCA

The TEC control printed circuit assembly is located on the sensor housing assembly, under the slanted shroud, next to the cooling fins and directly above the cooling fan.

- If the red LED located on the top edge of this assembly is not glowing the control circuit is not receiving power.

- Check the analyzer's power supply, the relay board's power distribution circuitry and the wiring connecting them to the PMT temperature control PCA.

12.6.13.1. TEC CONTROL TEST POINTS

Four test points are also located at the top of this assembly they are numbered left to right start with the T1 point immediately to the right of the power status LED. These test points provide information regarding the functioning of the control circuit.

To determine the current running through the control circuit, measure the voltage between **T1** and **T2**. Multiply that voltage by 10.

To determine the drive voltage being supplied by the control circuit to the TEC, measure the voltage between **T2** and **T3**.

- If this voltage is zero, the TEC circuitry is most likely open.

- If the voltage between T2 and T3 = 0 VDC and the voltage measured between T1 and T2 = 0 VDC there is most likely an open circuit or failed op amp on control PCA itself

- If the voltage between T2 and T3 = 0 VDC and the voltage measured between T1 to T2 is some voltage other than 0 VDC, the TEC is most likely shorted

T4 is tied directly to ground. To determine the absolute voltage on any one of the other test points make a measurement between that test point and T4.
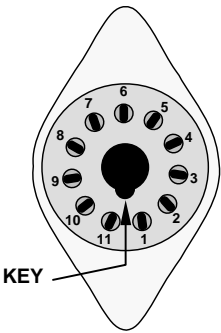
12.6.14. HIGH VOLTAGE POWER SUPPLY

The HVPS is located in the interior of the sensor module and is plugged into the PMT tube (refer to Figure 13-17). It requires 2 voltage inputs. The first is +15 which powers

the supply. The second is the programming voltage which is generated on the Preamp Board. This power supply is unlike a traditional PMT HVPS. It is like having 10 independent power supplies, one to each pin of the PMT. The test procedure below allows you to test each supply.

1. Check the **HVPS** test function via the front panel and record the reading level. Adjustment of the HVPS output level is covered in the hardware calibration procedure in Section 12.7.2.8.

2. Turn off the instrument.

3. Remove the cover and disconnect the 2 connectors at the front of the PMT housing.

4. Remove the end plate from the PMT housing.

5. Remove the HVPS/PMT assembly from the cold block inside the sensor. Un-plug the PMT.

6. Re-connect the 7 pin connector to the Sensor end cap, and power-up the instrument.

7. Check the voltages between the pairs of pins listed in Table 12-9. The result for each pair should be equal and approximately 10% of the reading level recorded in Step 1.

Table 12-9: Example of HVPS Power Supply Outputs

If **HVPS** reading = 700 VDC		
PIN PAIR	**NOMINAL READING**	
1 → 2	70 VDC	
2 → 3	70 VDC	
3 → 4	70 VDC	
4 → 5	70 VDC	
5 → 6	70 VDC	
6 → 7	70 VDC	
7 → 8	70 VDC	

8. Turn off the instrument power, and re-connect the PMT tube, and then re-assemble the sensor.

If any faults are found in the test, the HVPS must be replaced. There are no user serviceable parts inside the HVPS.

12.6.15. PNEUMATIC SENSOR ASSEMBLY

The pressure/flow sensor circuit board, located behind the sensor assembly, can be checked with a voltmeter using the following procedure, which assumes that the wiring is intact and that the motherboard and the power supplies are operating properly.

- Measure the voltage across TP1 and TP2, it should be 10.0 ± 0.25 V. If not, the board may be faulty.

- Measure the voltage across capacitor C2; it should be 5.0 ± 0.25 V. If not, the board may be faulty.

12.6.16. SAMPLE PRESSURE

Measure the voltage across test points TP1 and TP4. With the sample pump disconnected or turned off, this voltage should be 4500 ± 250 mV. With the pump running, it should be about 0.2 V less as the sample pressure drops by about 1 in-Hg-A from ambient pressure. If this voltage is significantly different, the pressure transducer S2 or the board may be faulty. A leak in the sample system to vacuum may also cause this voltage to be between about 0.6 and 4.5. Ensure that the front panel reading of the sample pressure is at about 1 in-Hg-A less than ambient pressure.

12.6.17. IZS OPTION

The zero/span valves and IZS options need to be enabled in the software (contact the factory on how to do this). Refer to Figure 3-19 and Figure 3-20 for a flow diagram with zero/span valve or IZS option.

- Check for the physical presence of the valves or the IZS option.

- Check that a working perm-tube is installed in the IZS oven assembly.

- Check front panel for correct software configuration. When the instrument is in SAMPLE mode, the front panel display should show CALS and CALZ buttons in the second line of the display. The presence of the buttons indicates that the option has been enabled in software. In addition, the IZS option is enabled if the TEST functions show a parameter named IZS TEMP.

The IZS option is heated with a proportional heater circuit and the temperature is maintained at 50° C ±1°. Check the **IZS TEMP** function via front panel display (refer to Section 4.1.1) and the **IZS_TEMP** signal voltage using the **SIGNAL I/O** function under the **DIAG** Menu (refer to Section 5.9.1).

At 50° C, the temperature signal from the IZS thermistor should be around 2500 mV.

12.6.18. BOX TEMPERATURE

The box temperature sensor (thermistor) is mounted on the motherboard at the bottom, right corner of the CPU board when looking at it from the front. It cannot be disconnected to check its resistance. Box temperature will vary with, but will always read about 5° C higher than, ambient (room) temperature because of the internal heating zones sample chamber and other devices.

To check the box temperature functionality, we recommend checking the **BOX_TEMP** signal voltage using the **SIGNAL I/O** function under the **DIAG** Menu (refer to Section 5.9.1).

At about 30° C (5° above typical room temperature), the signal should be around 1500 mV. We recommend using a certified or calibrated external thermometer / temperature sensor to verify the accuracy of the box temperature.

12.6.19. PMT TEMPERATURE

PMT temperature should be low and constant. It is more important that this temperature is maintained constant than it is to maintain it low. The PMT cooler uses a Peltier, thermo-electric element powered by 12 VDC from the switching power supply PS2. The temperature is controlled by a proportional temperature controller located on the preamplifier board. Voltages applied to the cooler element vary from +/- 0.1 to +/- 12

VDC. The temperature set point (hard-wired into the preamplifier board) will vary by about ±1° C due to component tolerances. The actual temperature will be maintained to within 0.1° C around that set point.

On power-up of the analyzer, the front panel enables the user to watch that temperature drop from about ambient temperature down to its set point of 6-8° C.

- If the temperature fails to drop after 20 minutes, there is a problem in the cooler circuit.

- If the control circuit on the preamplifier board is faulty, a temperature of -1° C is reported.

12.7. SERVICE PROCEDURES

This section contains some procedures that may need to be performed when a major component of the analyzer requires repair or replacement.

ATTENTION

COULD DAMAGE INSTRUMENT AND VOID WARRANTY

Servicing of circuit components requires electrostatic discharge protection, i.e. ESD grounding straps, mats and containers. Failure to use ESD protection when working with electronic assemblies will void the instrument warranty.

Refer to Section 13 for more information on preventing ESD damage.

12.7.1. DISK-ON-MODULE REPLACEMENT

Replacing the Disk-on-Module (DOM) will cause loss of all DAS data; it also may cause loss of some instrument configuration parameters unless the replacement DOM carries the exact same firmware version. Whenever changing the version of installed software, the memory must be reset. Failure to ensure that memory is reset can cause the analyzer to malfunction, and invalidate measurements. After the memory is reset, the A/D converter must be re-calibrated, and all information collected in Step 1 below must be re-entered before the instrument will function correctly. Also, zero and span calibration should be performed.

1. Document all analyzer parameters that may have been changed, such as range, auto-cal, analog output, serial port and other settings before replacing the DOM

2. Turn off power to the instrument, fold down the rear panel by loosening the mounting screws.

3. When looking at the electronic circuits from the back of the analyzer, locate the Disk-on-Module in the right-most socket of the CPU board.

4. The DOM should carry a label with firmware revision, date and initials of the programmer.

5. Remove the nylon fastener that mounts the DOM over the CPU board, and lift the DOM off the CPU. Do not bend the connector pins.

6. Install the new Disk-on-Module, making sure the notch at the end of the chip matches the notch in the socket.

7. It may be necessary to straighten the pins somewhat to fit them into the socket. Press the DOM all the way in and reinsert the offset clip.

8. Close the rear panel and turn on power to the machine.

9. If the replacement DOM carries a firmware revision, re-enter all of the setup information.

12.7.2. SENSOR MODULE REPAIR & CLEANING

CAUTION - GENERAL SAFETY HAZARD   Do not look at the UV lamp while the unit is operating. UV light can cause eye damage. Always use safety glasses made from UV blocking material when working with the UV Lamp Assembly. (Generic plastic glasses are not adequate).
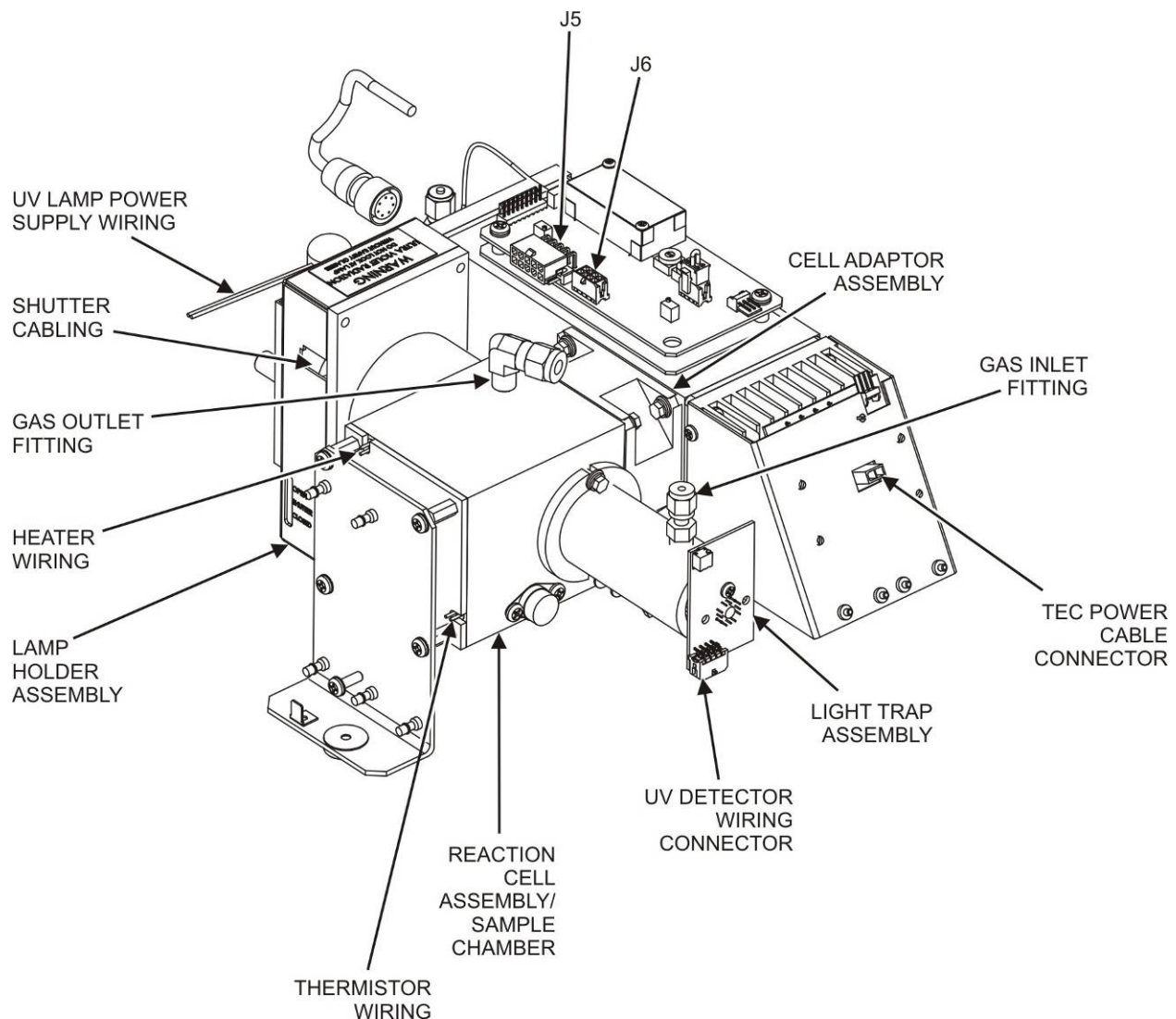
Figure 12-6:   Sensor Module Wiring and Pneumatic Fittings

IMPORTANT	IMPACT ON READINGS OR DATA

After any repair or service has been performed on the sensor module, the T100 should be allowed to warm up for 60 minutes.

Always perform a leak check (refer to Section 11.3.6) and calibrate the analyzer (refer to Section 9) before placing it back in service.

12.7.2.1. REMOVING AND REINSTALLING THE SENSOR MODULE

Several of the procedures in this section either require the sensor module to be removed from the instrument or are easier to perform if it has been removed.

To remove the Sensor Module:

1. Turn off the instrument power.

2. Open the top cover of the instrument:

- Remove the set screw located in the top, center of the rear panel.

- Remove the screws fastening the top cover to the unit (four per side).

- Lift the cover straight up.

3. Disconnect the sensor module pneumatic lines (refer to Figure 12-6

- Gas inlet line: 1/8" black Teflon® line with stainless steel fitting.

- Gas outlet line: 1/4" black Teflon® line with brass fitting.

4. Disconnect all electrical wiring to the Sensor Module:

- UV lamp power supply wiring

- Shutter cabling

- Reaction cell thermistor wiring (yellow)

- Reaction cell heater wiring (red)

- UV detector wiring

- TEC power cable

- PMT wiring (connectors J5 & J6 on the PMT preamplifier PCA)

5. Remove the three sensor module mounting screws.
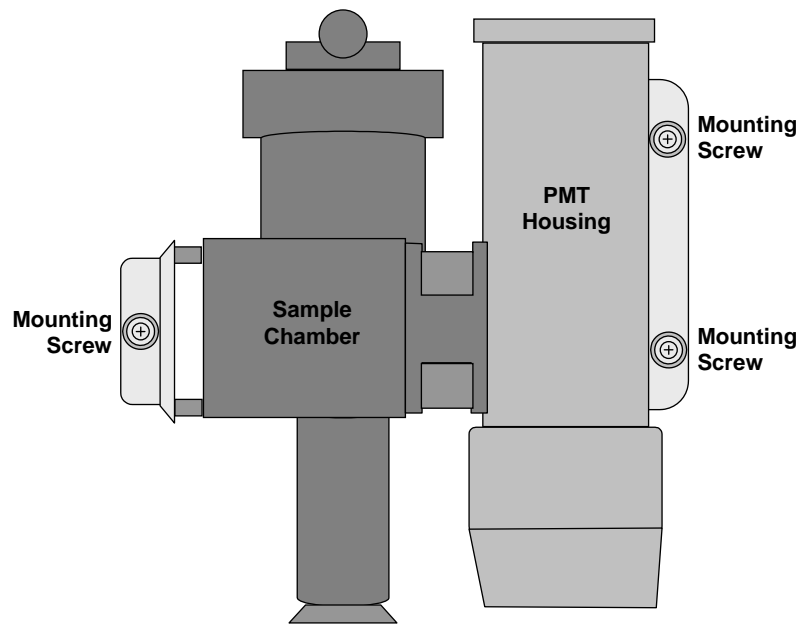
Figure 12-7:   Sensor Module Mounting Screws

Follow the above steps in reverse order to reinstall the sensor module.

12.7.2.2. CLEANING THE SAMPLE CHAMBER

IMPORTANT	IMPACT ON READINGS OR DATA
	The sample chamber should only be opened or cleaned on instructions from the Teledyne API Technical Support department.
	Be careful not to leave thumbprints on the interior of the sample chamber. The various oils that make up fingerprints fluoresce brightly under UV light and will significantly affect the accuracy of the analyzer's SO_2 measurement)

To clean the sample chamber:

1. Remove the sensor module as described in Section 12.7.2.1.

2. Remove the sample chamber mounting bracket by unscrewing the four bracket screws.
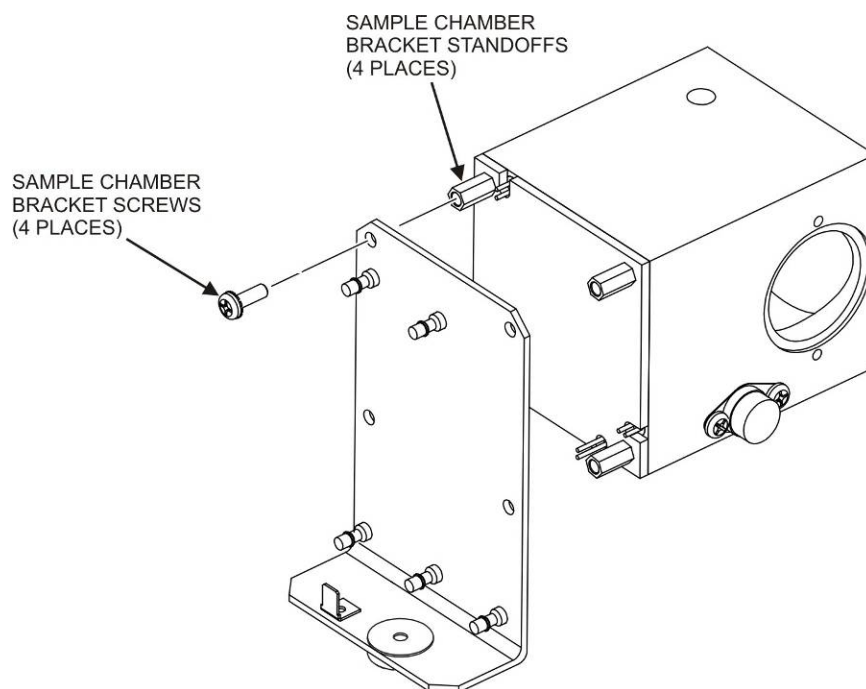
Figure 12-8:   Sample Chamber Mounting Bracket

3. Unscrew the 4 hexagonal standoffs.

4. Gently remove the chamber cover.

5. Using a lint-free cloth dampened with distilled water, wipe the inside surface of the chamber and the chamber cover.

6. Dry the chamber surfaces with a 2nd lint-free cloth.

7. Re-assemble the chamber and re-install the sensor module.

12.7.2.3. CLEANING THE PMT LENS AND PMT FILTER

IMPORTANT	IMPACT ON READINGS OR DATA

The sample chamber should only be opened or cleaned on instructions from the Teledyne API Technical Support Department.

Be careful not to leave thumbprints on the interior of the sample chamber. The various oils that make up fingerprints fluoresce brightly under UV light and will significantly affect the accuracy of the analyzer's SO_2 measurement).

To clean the PMT Lens and filter:

1. Remove the sensor module as described in Section 12.7.2.1.
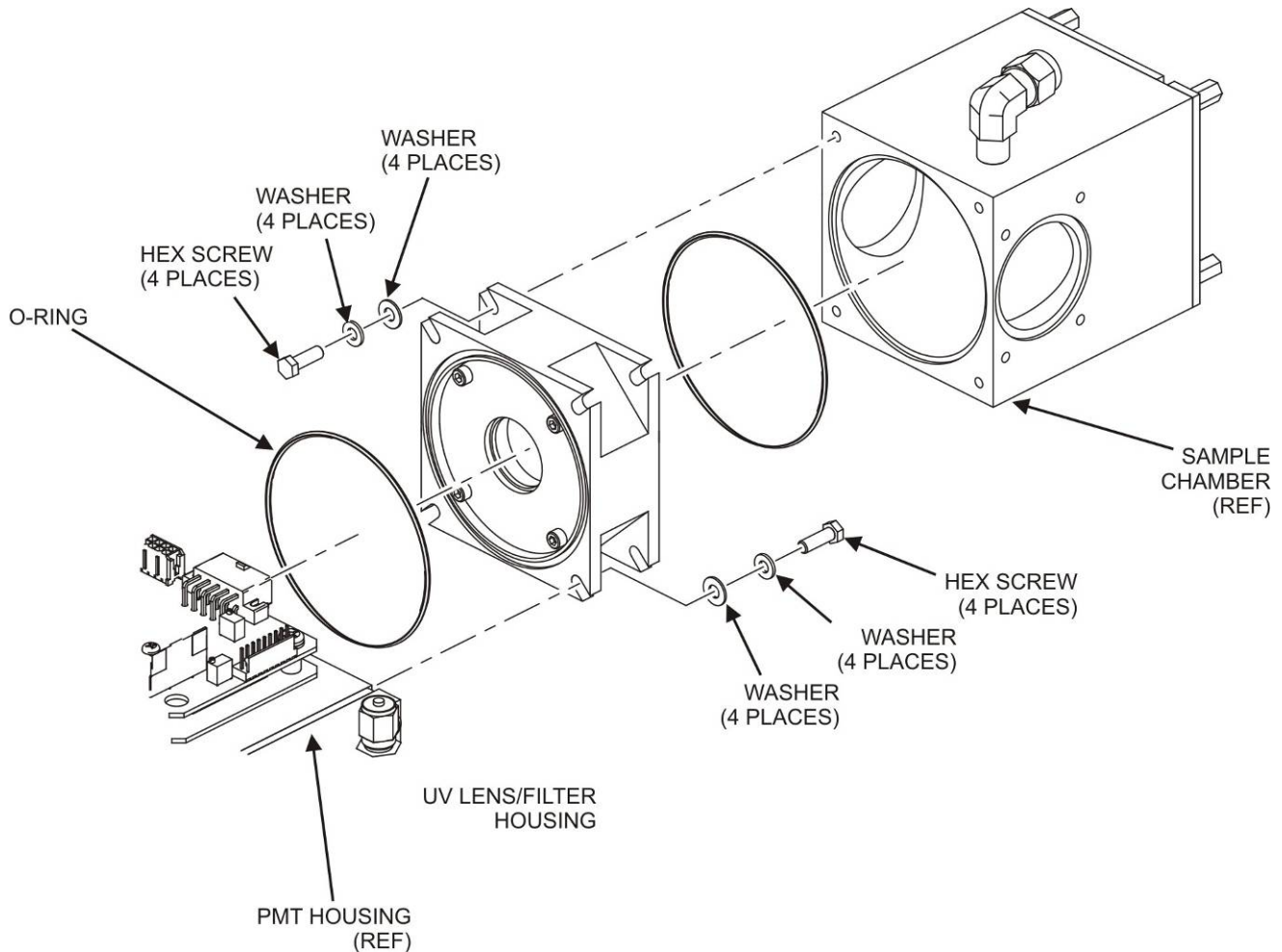
Figure 12-9:   Hex Screw Between Lens Housing and Sample Chamber

2. Remove the sample chamber from the PMT lens and filter housing by unscrewing the 4 hex screws that fasten the chamber to the housing.

3. Remove the four lens cover screws.
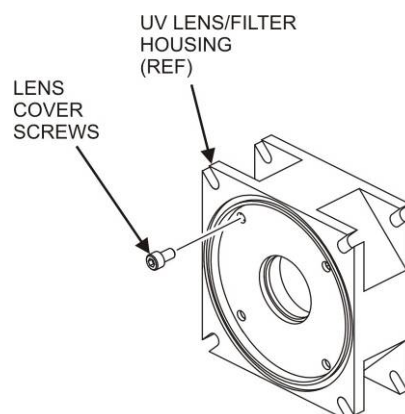
Figure 12-10:   UV Lens Housing / Filter Housing

4. Remove the lens/filter cover.

5. Carefully remove the PMT lens and set it aside on soft, lint-free cloth.

6. Remove the 3-piece, lens/filter spacer.

7. Carefully remove the PMT filter and set it aside on soft, lint-free cloth.
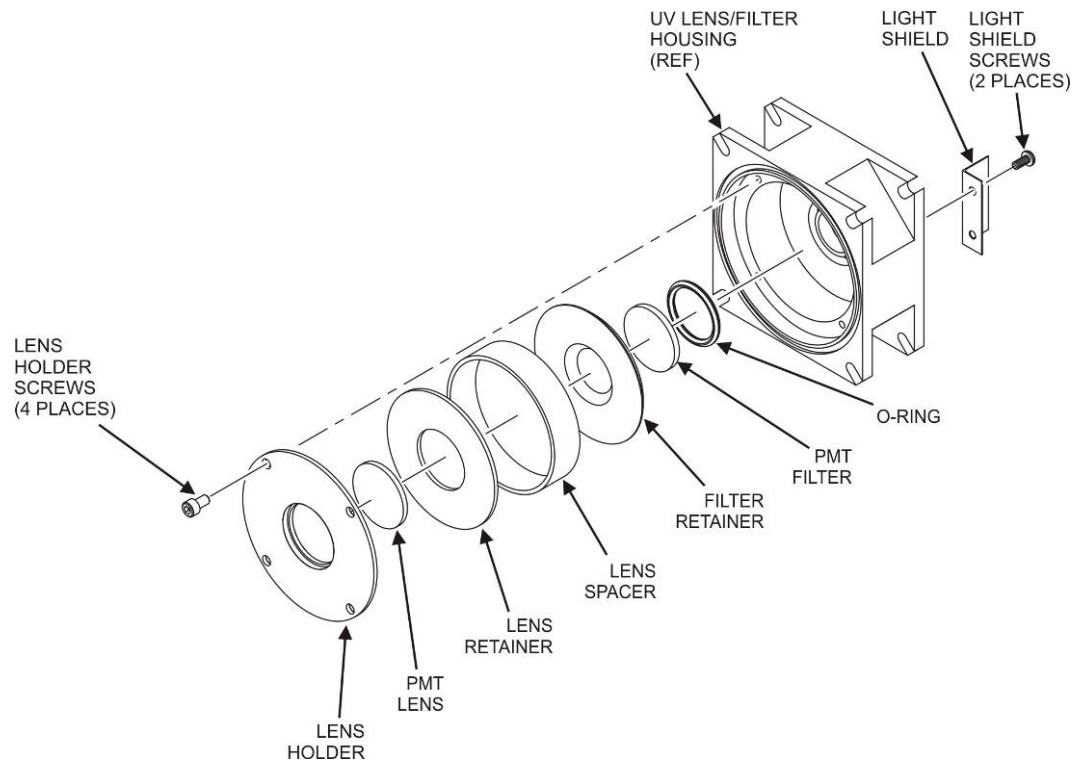
Figure 12-11:   PMT UV Filter Housing Disassembled

8. Using a lint-free cloth dampened with distilled water, clean the lens, the filter and all of the housing assembly mechanical parts.

9. Dry everything with a 2nd lint-free cloth.

10. Reassemble the lens/filter housing (refer to Figure 12-11 and Figure 12-10).

IMPORTANT	IMPACT ON READINGS OR DATA
	Use gloves and a clean plastic covered surface during assembly. Cleanliness of the inside of the light shield, the UV lens filter housing and the PMT lens is especially important.

Note	**Ensure to apply Loctite to the four lens holder screws and the two light shield screws.**

11. Reattach the lens / filter housing to the sample chamber.

12. Reattach the sample chamber to the PMT housing.

13. Reinstall the sensor module into the T100.

14. Close the instrument.

15. Turn the T100 on and let it warm up for 60 minutes.

16. Perform a leak check (refer to Section 11.3.6).

17. Calibrate the analyzer (refer to Section 9).

12.7.2.4. REPLACING THE UV FILTER/LENS

<table>
<tr><td>IMPORTANT</td><td>IMPACT ON READINGS OR DATA

Be careful not to leave thumbprints on the interior of the sample chamber. The various oils that make up fingerprints fluoresce brightly under UV light and will significantly affect the accuracy of the analyzer's SO$_2$ measurement).</td></tr>
</table>

<table>
<tr><td></td><td>**CAUTION - GENERAL SAFETY HAZARD**

Do not look at the UV lamp while the unit is operating. UV light can cause eye damage. Always use safety glasses made from UV blocking material when working with the UV Lamp Assembly. (Generic plastic glasses are not adequate).</td></tr>
</table>

To replace the UV filter lens:

1. Turn off the instrument's power and remove the power cord from the instrument.

2. Unplug J4 connector from the motherboard to allow tool access.

3. Alternatively, remove the sensor module as described in Section 12.7.2.1.

4. Remove 4 screws from the shutter cover (refer to Figure 12-13) and remove the cover.

5. Remove 4 screws from the UV filter retainer.
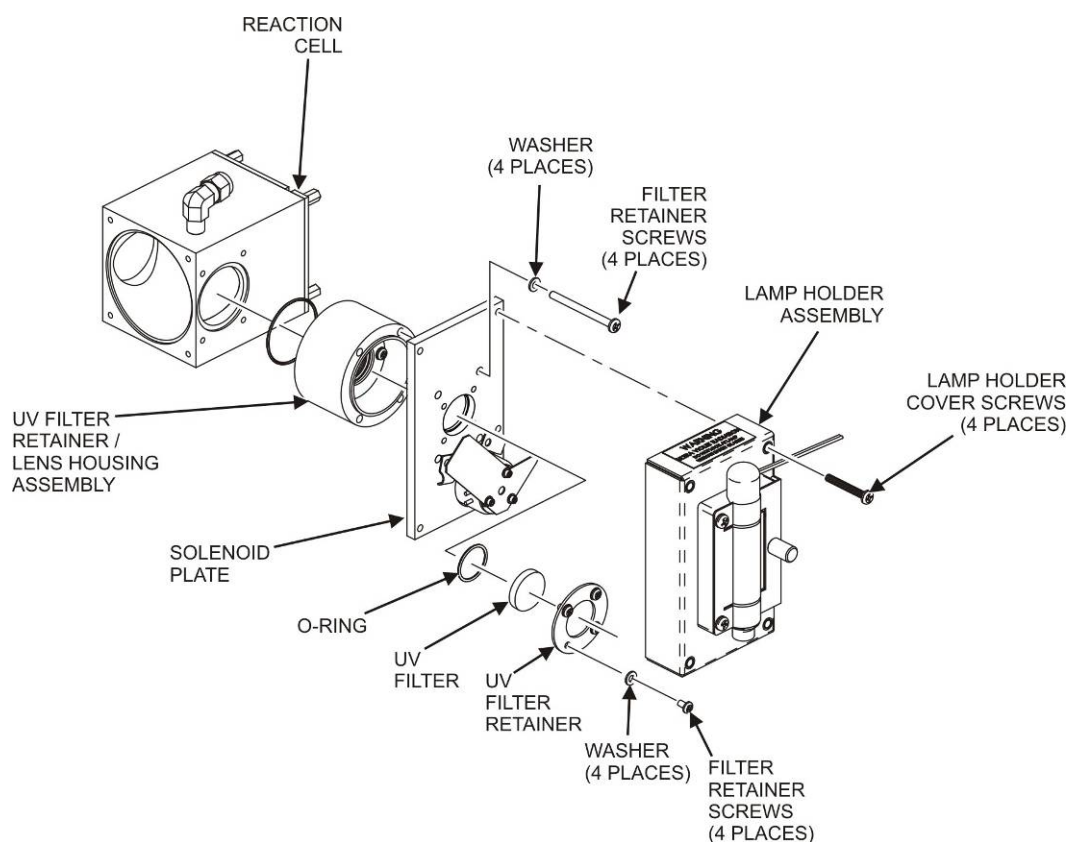
Figure 12-12:   Disassembling the Shutter Assembly

6.   Carefully remove the UV filter.

7.   Install the UV filter.

8.   Handle carefully and never touch the filter's surface.

9.   UV filter's wider ring side should be facing out.

10. Install UV filter retainer and tighten screws.

11. Install the shutter cover and minifit connector. Tighten 4 shutter cover screws.

12. Reinstall the sensor module and Plug J4 connector into the motherboard.

12.7.2.5. ADJUSTING THE UV LAMP (*PEAKING THE LAMP*)

There are three ways in which ambient conditions can affect the UV Lamp output and therefore the accuracy of the SO_2 concentration measurement. These are:

Line Voltage Change: UV lamp energy is directly proportional to the line voltage. This can be avoided by installing adequate AC Line conditioning equipment such as a UPS/surge suppressor.

Lamp Aging - Over a period of months, the UV energy will show a downward trend and can be up to 50% in the first 90 days, and then a slower rate, until the end of useful life of the lamp. Periodically running the UV lamp calibration routine (refer to Section 5.9.6) will compensate for this until the lamp output becomes too low to function at all.

Note	As the lamp degrades over time, the software for the CPU compensates for the loss of UV output.

Lamp Positioning – The UV output level of the lamp is not even across the entire length of the lamp. Some portions of the lamp shine slightly more brightly than others. At the factory the position of the UV lamp is adjusted to optimize the amount of UV light shining through the UV filter/lens and into the reaction cell. Changes to the physical alignment of the lamp can affect the analyzers ability to accurately measure SO_2.
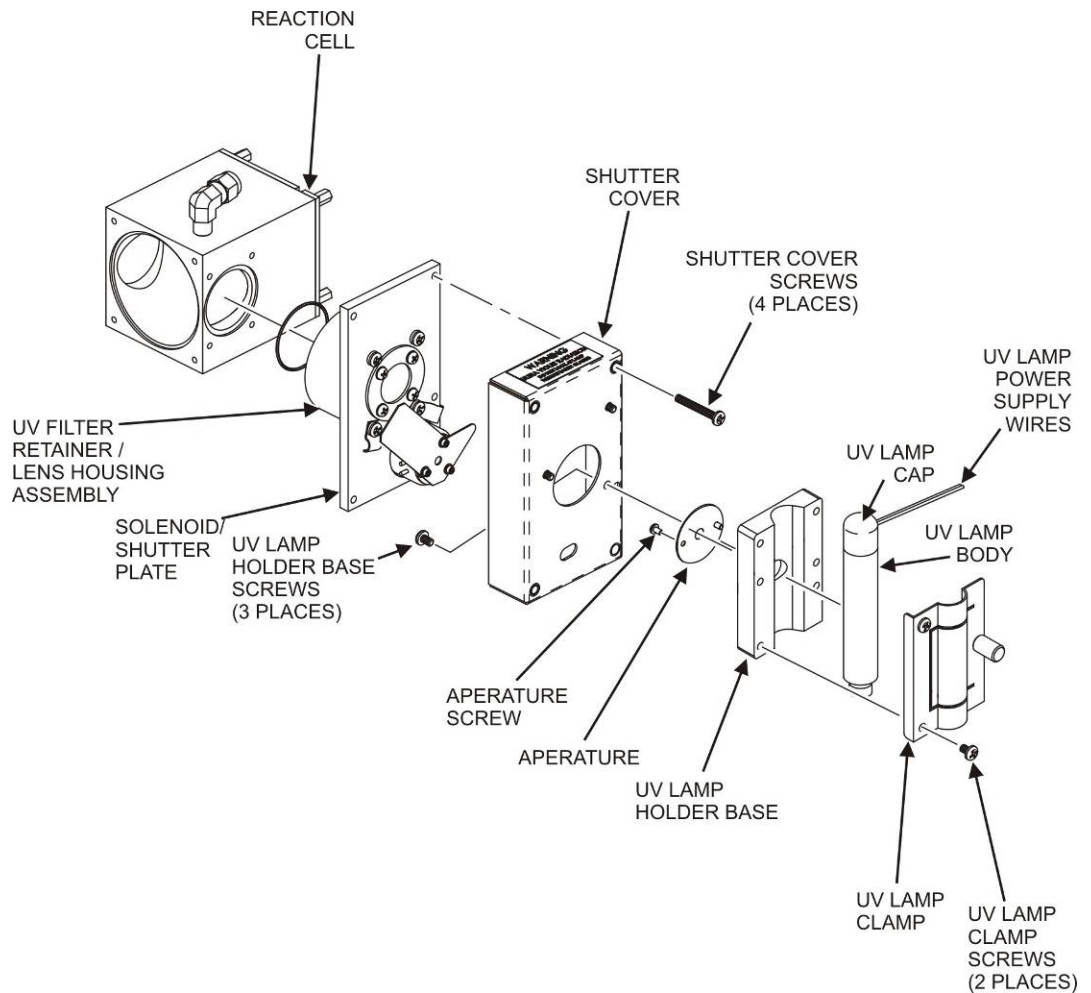
Figure 12-13:   Shutter Assembly

CAUTION - GENERAL SAFETY HAZARD

 Do not look at the UV lamp while the unit is operating. UV light can cause eye damage. Always use safety glasses made from UV blocking material when working with the UV Lamp Assembly. (Generic plastic glasses are not adequate).

---

1. Set the analyzer display to show the signal I/O function, **UVLAMP_SIGNAL** (refer to Section 12.1.3). **UVLAMP_SIGNAL** is function 33.

2. Slightly loosen the large brass thumbscrew located on the shutter housing (refer to Figure 12-14) so that the lamp can be moved.
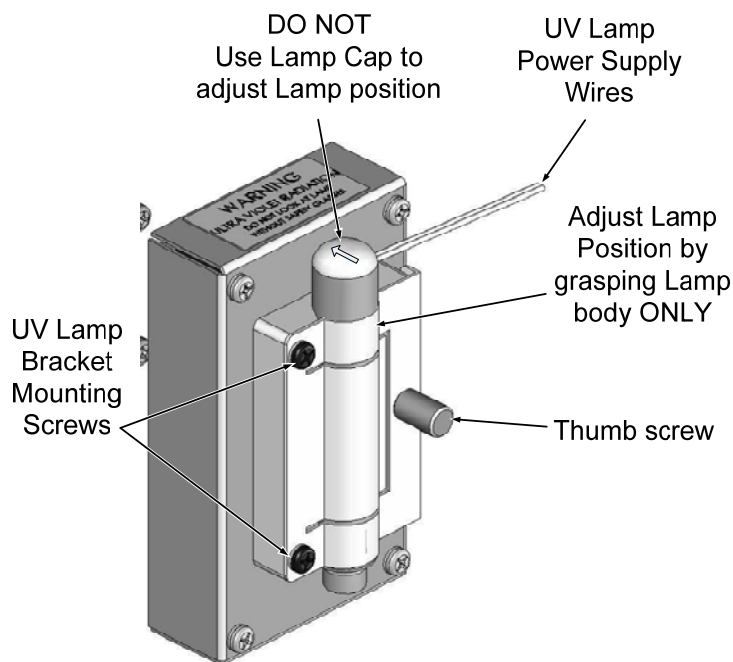
Figure 12-14.   UV Lamp Adjustment

ATTENTION   **COULD DAMAGE INSTRUMENT AND VOID WARRANTY**

DO NOT grasp the UV lamp by its cap when changing its position - always grasp the main body of the lamp (refer to Figure 12-13). Inattention to this detail could twist and potentially disconnect the lamp's power supply wires.

3. While watching the **UVLAMP_SIGNAL** reading, slowly rotate the lamp or move it back and forth vertically until the **UVLAMP_SIGNAL** reading is at its maximum.

4. Compare the **UVLAMP_SIGNAL** reading to the information in Table 12-10 and follow the instructions there.

Table 12-10:   UV Lamp Signal Troubleshooting

UVLAMP_SIGNAL	ACTION TO BE TAKEN
3500mV±200mV.	No Action Required
> 4900mV at any time.	Adjust the UV reference detector potentiometer (Figure 12-15) until **UVLAMP_SIGNAL** reads approximately 3600mV before continuing to adjust the lamp position.
>3700mV or < 3300mV	Adjust the UV reference detector potentiometer (Figure 12-15) until **UVLAMP_SIGNAL** reads as close to 3500mV as possible.
.< 600mV	Replace the lamp (Section 12.7.2.6.
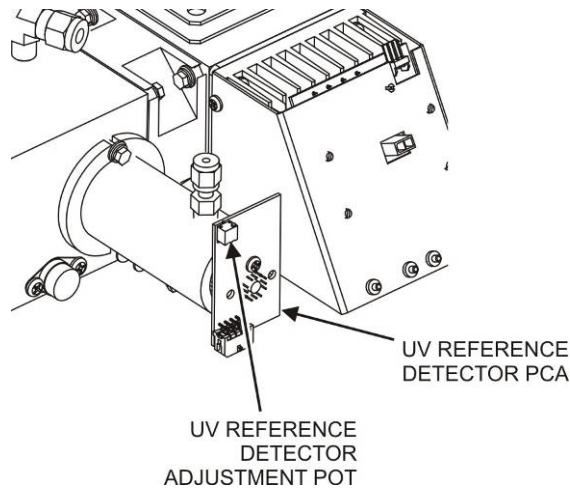
Figure 12-15:   Location of UV Reference Detector Potentiometer

5. Finger tighten the thumbscrew.

⚠	**CAUTION - GENERAL SAFETY HAZARD** **DO NOT over tighten the thumbscrew, as over-tightening can cause breakage to the lamp and consequently release mercury into the area.**

12.7.2.6. **REPLACING THE UV LAMP**

⚠	**CAUTION - GENERAL SAFETY HAZARD** **Do not look at the UV lamp while the unit is operating. UV light can cause eye damage. Always use safety glasses made from UV blocking material when working with the UV Lamp Assembly. (Generic plastic glasses are not adequate).**

1. Turn off the analyzer.

2. Disconnect the UV lamp from its power supply.

3. You can find the power supply connector by following the two, white UV Lamp power supply wires from the lamp to the power supply.

4. Loosen, but do not remove the two UV lamp bracket screws and the large brass thumbscrew located (refer to Figure 12-13 and Figure 12-14) on the shutter housing so that the lamp can be moved.

ATTENTION

- -

COULD DAMAGE INSTRUMENT AND VOID WARRANTY

DO NOT grasp the UV lamp by its cap when changing its position - always grasp the main body of the lamp (refer to Figure 12-13) Inattention to this detail could twist and potentially disconnect the lamp's power supply wires.

- -

5. Remove the UV Lamp by pulling it straight up.

6. Insert the new UV lamp into the bracket.

7. Tighten the two UV lamp bracket screws, but leave the brass thumb screw un-tightened.

8. Connect the new UV lamp to the power supply.

9. Turn the instrument on and perform the UV adjustment procedure as defined in section 12.7.2.5.

10. Finger tighten the thumbscrew.

⚠	**CAUTION - GENERAL SAFETY HAZARD** **DO NOT over tighten the thumbscrew, as over-tightening can cause breakage to the lamp and consequently release mercury into the area.**

11. Perform a lamp calibration procedure (refer to Section 5.9.6) and a zero point and span point calibration (refer to Section 9).

12.7.2.7. REPLACING THE PMT, HVPS OR TEC

The PMT should last for the lifetime of the analyzer. However, in some cases, the high voltage power supply (HVPS) or the thermo-electric cooler (TEC) may fail.

IMPORTANT **When removing the PMT housing end plate cover for the Sensor Assembly, ensure to replace the 5 desiccant bags inside the housing.**
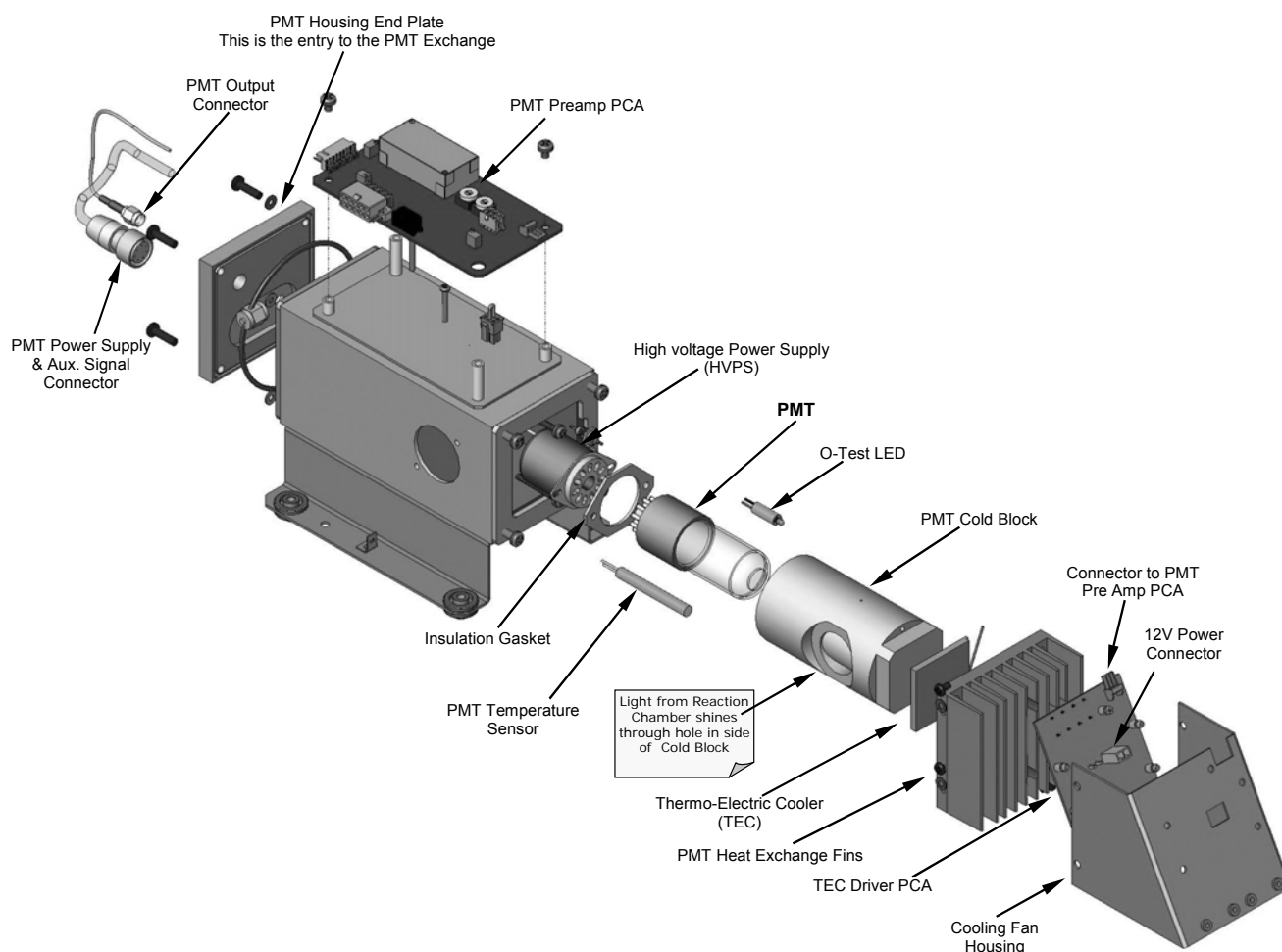
Figure 12-16:   PMT Assembly - Exploded View

To replace the PMT, the HVPS or the TEC:

1. Remove the sensor module as described in Section 12.7.2.1.

2. Remove the entire sensor module assembly from the.

3. Remove the reaction cell assembly.

4. Remove the two connectors on the PMT housing end plate facing towards the front panel.

5. Remove the end plate itself (4 screws with plastic washers).

6. Remove the desiccant bags inside the PMT housing.

7. Along with the plate, slide out the OPTIC TEST LED and the thermistor that measures the PMT temperature.

• Both may be coated with a white, thermal conducting paste. Do not contaminate the inside of the housing or the PMT tube with this grease.

8. Unscrew the PMT assembly. It is held to the cold block by two plastic screws.

• Because the threads of the plastic screws are easily damaged it is highly recommended to use new screws when reassembling the unit.

9. Carefully take out the assembly consisting of the HVPS, the gasket and the PMT.

10. Change the PMT or the HVPS or both, clean the PMT glass tube with a clean, anti-static wipe and **DO NOT TOUCH** it after cleaning.

11. If the cold block or TEC is to be changed disconnect the TEC driver board from the preamplifier board.

- Remove the cooler fan duct (4 screws on its side) including the driver board.

- Disconnect the driver board from the TEC and set the sub-assembly aside.

- Remove the end plate with the cooling fins (4 screws) and slide out the PMT cold block assembly, which contains the TEC.

- Unscrew the TEC from the cooling fins and the cold block and replace it with a new unit.

12. Re-assemble the TEC subassembly in reverse order.

ATTENTION

— - — - — - — - — - — - — - — - — - — - — - — - — - — - — - —

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The thermo-electric cooler needs to be mounted flat to the heat sink. If there is any significant gap, the TEC might burn out. Ensure to apply heat sink paste before mounting it and tighten the screws evenly and cross-wise.

— - — - — - — - — - — - — - — - — - — - — - — - — - — - — - —

- Ensure to use thermal grease between TEC and cooling fins as well as between TEC and cold block.

- Align the side opening in the cold block with the hole in the PMT housing where the sample Chamber attaches.

- Evenly tighten the long mounting screws for good thermal conductivity.

13. Re-insert the TEC subassembly. Ensure that the O-ring is placed properly and the assembly is tightened evenly.

14. Re-insert the PMT/HVPS subassembly.

- Don't forget the gasket between HVPS and PMT.

- Use new plastic screws to mount the PMT assembly on the PMT cold block.

15. Insert the LED and thermistor into the cold block.

16. Replace the desiccant bags with five new desiccant bags.

17. Carefully replace the end plate.

- Ensure that the O-ring is properly in place. Improperly placed O-rings will cause leaks, which – in turn – cause moisture to condense on the inside of the cooler causing the HVPS to short out.

18. Reconnect the cables and the reaction cell

- Be sure to tighten these screws evenly.

19. Replace the sensor assembly into the chassis and fasten with four screws and washers.

20. Perform a leak check the system.

21. Power up the analyzer and verify the basic operation of the analyzer using the ETEST and OTEST features (refer to Section 6.9.5 and 6.9.6) or by measuring calibrated zero and span gases.

22. Allow the instrument to warm up for 60 minutes.

23. Perform a PMT Hardware calibration (refer to Section 12.7.2.8).

24. Perform a zero point and span calibration (refer to Section 9).

12.7.2.8. PMT HARDWARE CALIBRATION (*FACTORY CAL*)

The sensor module hardware calibration adjusts the slope of the PMT output when the instrument's slope and offset values are outside of the acceptable range and all other more obvious causes for this problem have been eliminated.
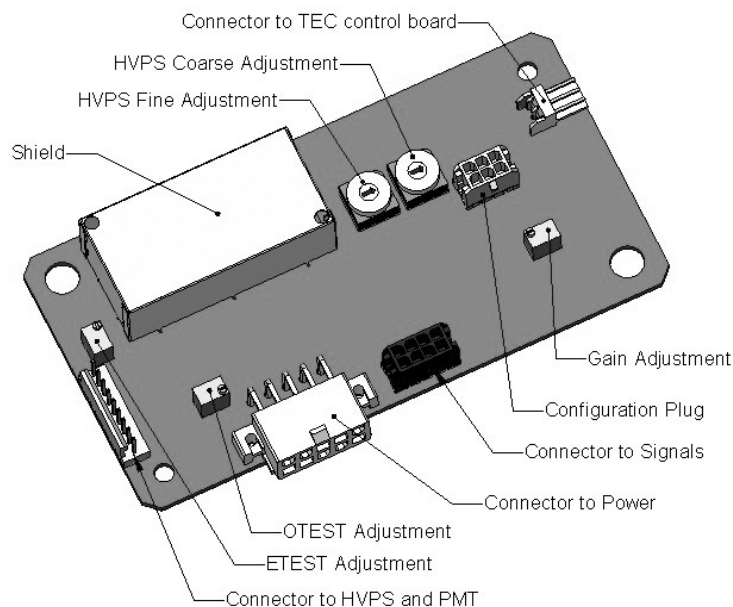
Figure 12-17:   Pre-Amplifier Board (Preamp PCA) Layout

1.   Set the instrument reporting range type to **SNGL** (refer to Section 5.4.3.1).

2.   Perform a zero–point calibration using zero air (refer to Section 9).

3.   Let the instrument stabilize by allowing it to run for one hour.

4.   Adjust the UV Lamp (refer to Section 12.7.2.5).

5.   Perform a **LAMP CALIBRATION** procedure (refer to Section 5.9.6).

6.   Locate the Preamp PCA (refer to Figure 12-16).

7.   Locate the Following Components On the Preamp PCA (Figure 12-17):

8.   HVPS coarse adjustment switch (Range 0-9, then A-F).

9.   HVPS fine adjustment switch (Range 0-9, then A-F).

10. Gain adjustment potentiometer (Full scale is 10 to 12 turns).

11. Set the HVPS coarse adjustment to its minimum setting (0).

12. Set the HVPS fine adjustment switch to its maximum setting (F).

13. Turn the gain adjustment potentiometer clockwise to its maximum setting.

14. Set the front panel display to show **STABIL** (refer to Section 4.1.1).

15. Feed span gas into the analyzer.

16. Wait until the **STABIL** value is below 0.5 ppb.

IMPORTANT	**IMPACT ON READINGS OR DATA**
	Use a span gas equal to 80% of the reporting range. Example: for a reporting range of 500 ppb, use a span gas of 400 ppb.

---

17. **Scroll** to the **OFFSET** function and record the value.

18. Scroll to the **NORM PMT** value.

ATTENTION	**COULD DAMAGE INSTRUMENT AND VOID WARRANTY**
	Do not overload the PMT by accidentally setting both adjustment switches to their maximum setting. This can cause permanent damage to the PMT.

---

19. Determine the target **NORM PMT** value according to the following formulas.

- If the reporting range is set for $\leq 2,000$ ppb (the instrument will be using the 2,000 ppb physical range):

  Target **NORM PMT** = (2 x span gas concentration) + **OFFSET**

- If the reporting range is set for $\geq 2,001$ ppb(the instrument will be using the 20,000 ppb physical range):

  Target **NORM PMT** = (0.181 x span gas concentration) + **OFFSET**

  EXAMPLE: If the **OFFSET IS** 33 mV, the Reporting Range is 500 ppb, the span gas should be 400 ppb and the calculation would be:
  Target **NORM PMT**   =   (2 x 400) + 33 mV
  Target **NORM PMT**   =   833 mV

20. Set the HVPS coarse adjustment switch to the lowest setting that will give you more than the target NORM PMT signal from Step 16.

- The coarse adjustment typically increments the **NORM PMT** signal in 100-300 mV steps.

21. Adjust the HVPS fine adjustment such that the NORM PMT value is at or just above the target NORM PMT signal from Step 16.

22. Continue adjusting the both the coarse and fine switches until norm PMT is as close to (but not below) the target NORM PMT signal from Step 16.

23. Adjust gain adjustment potentiometer until the NORM PMT value is ±10 mV of the target level from Step 16.

24. Perform span and zero-point calibrations (refer to Section 9) to normalize the sensor response to its new PMT sensitivity.

25. Review the slope and offset values, and compare them to the values in Table 9-5.

12.8. FREQUENTLY ASKED QUESTIONS (FAQS)

The following list contains some of the most commonly asked questions relating to the T100 SO$_2$ Analyzer.

QUESTION	ANSWER
Why is the **ZERO** or **SPAN** button not displayed during calibration?	The T100 disables these buttons when the expected span or zero value entered by the users is too different from the gas concentration actually measured value at the time. This is to prevent the accidental recalibration of the analyzer to an out-of-range response curve.-EXAMPLE: The span set point is 400 ppb but gas concentration being measured is only 50 ppb.-For more information, refer to Section 12.4.4 and Section 12.4.5.
Why does the **ENTR** button sometimes disappear on the Front Panel Display?	During certain types of adjustments or configuration operations, the **ENTR** button will disappear if you select a setting that is nonsensical (such as trying to set the 24-hour clock to 25:00:00) or out of the allowable range for that parameter (such as selecting a DAS hold off period of more than 20 minutes).-Once you adjust the setting in question to an allowable value, the **ENTR** button will re-appear.
How do I enter or change the value of my Span Gas?	Press the **CONC** button found under the **CAL** or **CALS** menus of the main SAMPLE menu to enter the expected SO$_2$ span concentration.-Refer to Section 3.4.4.1 or for more information.
Why does the analyzer not respond to span gas?	Section 12.4.4 has some possible answers to this question.
Can I automate the calibration of my analyzer?	Any analyzer with zero/span valve or IZS option can be automatically calibrated using the instrument's AutoCal feature.-However, the accuracy of the IZS option's permeation tube is ±5%. While this may be acceptable for basic calibration checks, the IZS option is not permitted as a calibration source in applications following US EPA protocols. -To achieve highest accuracy, it is recommended to use cylinders of calibrated span gases in combination with a zero air source. Teledyne API offers a zero air generator Model 701 and a gas dilution calibrator Model T700 for this purpose.
What do I do if the concentration on the instrument's front panel display does not match the value recorded or displayed on my data logger even if both instruments are properly calibrated?	This most commonly occurs for one of the following reasons: -A difference in circuit ground between the analyzer and the data logger or a wiring problem;-A scale problem with the input to the data logger. -The analog outputs of the T100 can be manually adjusted to compensate for either or both of these effects, refer to 5.9.3.4; -The analog outputs are not calibrated, which can happen after a firmware upgrade. -Both the electronic scale and offset of the analog outputs can be adjusted (refer to Section 5.9.3.2). Alternately, use the data logger itself as the metering device during calibrations procedures.
How do I perform a leak check?	Refer to Section 11.3.6.
How do I measure the sample flow?	Sample flow is measured by attaching a calibrated flow meter to the sample inlet port when the instrument is operating. The sample flow should be 650 cm³/min $\pm$10%. Section 11.3.6 includes detailed instructions on performing a check of the sample gas flow.
How often do I need to change the particulate filter?	Once per week. Table 11-1 contains a maintenance schedule listing the most important, regular maintenance tasks.
What is the averaging time for an T100?	The default averaging time, optimized for ambient pollution monitoring, is 240 seconds for stable concentrations and 20 seconds for rapidly changing concentrations; Refer to 13.7.1 for more information.
My analyzer has the optional, user - configurable analog output channels.	Instructions for this can be found in the Manual Addendum for Configurable Analog Output, PN 06270.

QUESTION	ANSWER
How do I program and use them?	
How long does the sample pump last?	The sample pump should last about one year and the pump diaphragms should to be replaced annually or when necessary. Use the **PRES** test function displayed via the front panel to see if the diaphragm needs replacement (refer to Section 12.1.2).
Do I need a strip chart recorder or external data logger?	No, the T100 is equipped with a very powerful internal data acquisition system. Section 0 describes the setup and operation in detail.

12.9. TECHNICAL ASSISTANCE

If this manual and its troubleshooting / repair sections do not solve your problems, technical assistance may be obtained from:

Teledyne API, Technical Support ,
9480 Carroll Park Drive
San Diego, California 92121-5201USA

Toll-free Phone: 800-324-5190
Phone: 858-657-9800
Fax: 858-657-9816
Email: api-customerservice@teledyne.com
Website: http://www.teledyne-api.com/

Before you contact Teledyne API' Technical Support, fill out the problem report form in Appendix C, which is also available online for electronic submission at http://www.teledyne-api.com/forms/.

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13. PRINCIPLES OF OPERATION

This section describes the principles of operation for the T100 SO$_2$ analyzer (Section 13.1), for the optional O$_2$ sensor (Section 13.2) and for the optional CO$_2$ sensor (Section 13.3). It also describes the principles of operation for pneumatics (Section 13.4), electronics (Section 13.5), communication interfaces (13.6) and software (13.7).

13.1. SULFUR DIOXIDE (SO$_2$) SENSOR PRINCIPLES OF OPERATION

The T100 UV Fluorescence SO$_2$ Analyzer is a microprocessor controlled analyzer that determines the concentration of sulfur dioxide (SO$_2$), in a sample gas drawn through the instrument. It requires that sample and calibration gases be supplied at ambient atmospheric pressure in order to establish a constant gas flow through the sample chamber where the sample gas is exposed to ultraviolet light; this exposure causes the SO$_2$ molecules to change to an excited state (SO$_2$*). As these SO$_2$* molecules decay into SO$_2$ they fluoresce. The instrument measures the amount of fluorescence to determine the amount of SO$_2$ present in the sample gas.

Calibration of the instrument is performed in software and usually does not require physical adjustments to the instrument. During calibration, the microprocessor measures the sensor output signal when gases with known amounts of SO$_2$ at various concentrations are supplied and stores these measurements in memory. The microprocessor uses these calibration values along with other performance parameters such as the PMT dark offset, UV lamp ratio and the amount of stray light present and measurements of the temperature and pressure of the sample gas to compute the final SO$_2$ concentration.

This concentration value and the original information from which it was calculated are stored in the unit's internal data acquisition system and reported to the user through a vacuum fluorescent display or as electronic data via several communication ports.

This concentration value and the original information from which it was calculated are stored in the unit's internal data acquisition system (refer to Section 0) and reported to the user through a vacuum fluorescent display or several communication ports.

13.1.1. SO$_2$ ULTRAVIOLET FLUORESCENCE MEASUREMENT PRINCIPLE

The physical principle upon which the T100's measurement method is based is the fluorescence that occurs when sulfur dioxide (SO$_2$) is changed to excited state (SO$_2$*) by ultraviolet light with wavelengths in the range of 190 nm-230 nm. This reaction is a two-step process.

The first stage (Equation 13-1) occurs when SO_2 molecules are struck by photons of the appropriate ultraviolet wavelength. In the case of the T100, a band pass filter between the source of the UV light and the affected gas limits the wavelength of the light to approximately 214 nm. The SO_2 absorbs some of energy from the UV light causing one of the electrons of the SO_2 molecule to move to a higher energy orbital state.

$$SO_2 + hv_{214nm} \xrightarrow{Ia} SO_2 *$$
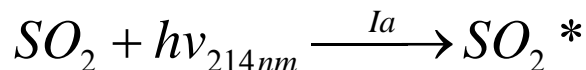
(Equation 13-1)

The amount SO_2 converted to SO_2* in the sample chamber is dependent on the average intensity of the UV light (*Ia*) and not its peak intensity because the intensity of UV light is not constant in every part of the sample chamber. Some of the photons are absorbed by the SO_2 as the light travels through the sample gas.
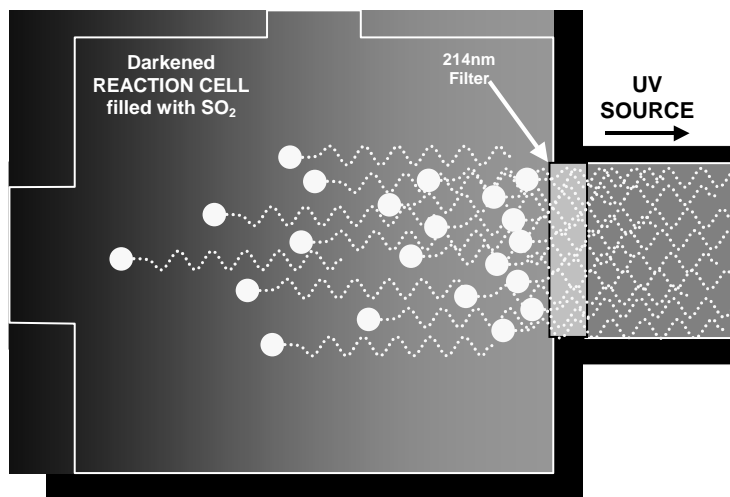
Figure 13-1:   UV Absorption

The equation for defining the average intensity of the UV light (*Ia*) is:

$$Ia = I_0 \left[1 - exp\left(- ax(SO_2) \right) \right]$$

(Equation 13-2)

Where:

I_0 = Intensity of the excitation UV light.

a = The absorption coefficient of SO_2 (a constant).

SO_2 = Concentration of SO_2 in the sample chamber.

x = The distance between the UV source and the SO_2 molecule(s) being affected (path length).

The second stage of this reaction occurs after the SO_2 reaches its excited state (SO_2^*). Because the system will seek the lowest available stable energy state, the SO_2^* molecule quickly returns to its ground state (Equation 10-3) by giving off the excess energy in the form of a photon ($h\nu$). The wavelength of this fluoresced light is also in the ultraviolet band but at a longer (lower energy) wavelength centered at 330nm.

$$SO_2^* \longrightarrow SO_2 + h\nu_{330nm}$$
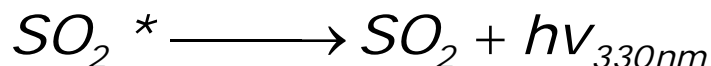
(Equation 13-3)

The amount of detectable UV given off by the decay of the SO_2^* is affected by the rate at which this reaction occurs (k).

$$F = k(SO_2^*)$$

(Equation 13-4)

Where:

F   = the amount of fluorescent light given off.

k   = The rate at which the SO_2^* decays into SO_2.

SO_2^* = Amount of excited-state SO_2 in the sample chamber.

Therefore:

$$(SO_2^*) \xrightarrow{kF} SO_2 + h\nu_{330nm}$$
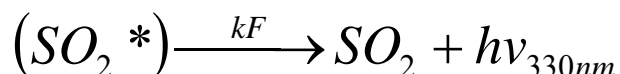
(Equation 13-5)

Finally, the function (k) is affected by the temperature of the gas. The warmer the gas, the faster the individual molecules decay back into their ground state and the more photons of UV light are given off per unit of time.

Given that the absorption rate of SO_2 (a) is constant, the amount of fluorescence (F) is a result of:

- The amount of SO_2^* created which is affected by the variable factors from (Equation 13-2) above: concentration of SO_2; intensity of UV light (I_0); path length of the UV light(x) and;

- The amount of fluorescent light created which is affected by the variable factors from (Equation 13-5): the amount of SO_2^* present and the rate of decay (k) which changes based on the temperature of the gas.

When and the intensity of the light (I_0) is known; path length of excited light is short (x); the temperature of the gas is known and compensated for so that the rate of SO_2^*decay is constant (k). and; no interfering conditions are present (such as interfering gases or stray light); the amount of fluorescent light emitted (F) is directly related to the concentration of the SO_2 in the Sample Chamber.

The Model 100 E UV Fluorescence SO_2 Analyzer is specifically designed to create these circumstances.

- The light path is very short (**x**).

- A reference detector measures the intensity of the available excitation UV light and is used to remove effects of lamp drift (**I_0**).

- The temperature of the sample gas is measured and controlled via heaters attached to the sample chamber so that the rate of decay (**k**) is constant.

- A special hydrocarbon scrubber removes the most common interfering gases from the sample gas.

- And finally, the design of the sample chamber reduces the effects of stray light via its optical geometry and spectral filtering.

The net result is that any variation in UV fluorescence can be directly attributed to changes in the concentration of SO_2 in the sample gas.

13.1.2. THE UV LIGHT PATH

The optical design of the T100's sample chamber optimizes the fluorescent reaction between SO_2 and UV Light (refer to Figure 13-2) and assure that only UV light resulting from the decay of SO_2* into SO_2 is sensed by the instruments fluorescence detector.

UV radiation is generated by a lamp specifically designed to produce a maximum amount of light of the wavelength needed to excite SO_2 into SO_2* (214 nm) and a special reference detector circuit constantly measures lamp intensity (refer to (Equation 13-2)). A Photo Multiplier Tube (PMT) detects the UV given off by the SO_2* decay (330 nm) and outputs an analog signal. Several focusing lenses and optical filters ensure that both detectors are exposed to an optimum amount of only the right wavelengths of UV. To further assure that the PMT only detects light given off by decaying SO_2* the pathway of the excitation UV and field of view of the PMT are perpendicular to each other and the inside surfaces of the sample chamber are coated with a layer of black Teflon$^®$ that absorbs stray light.
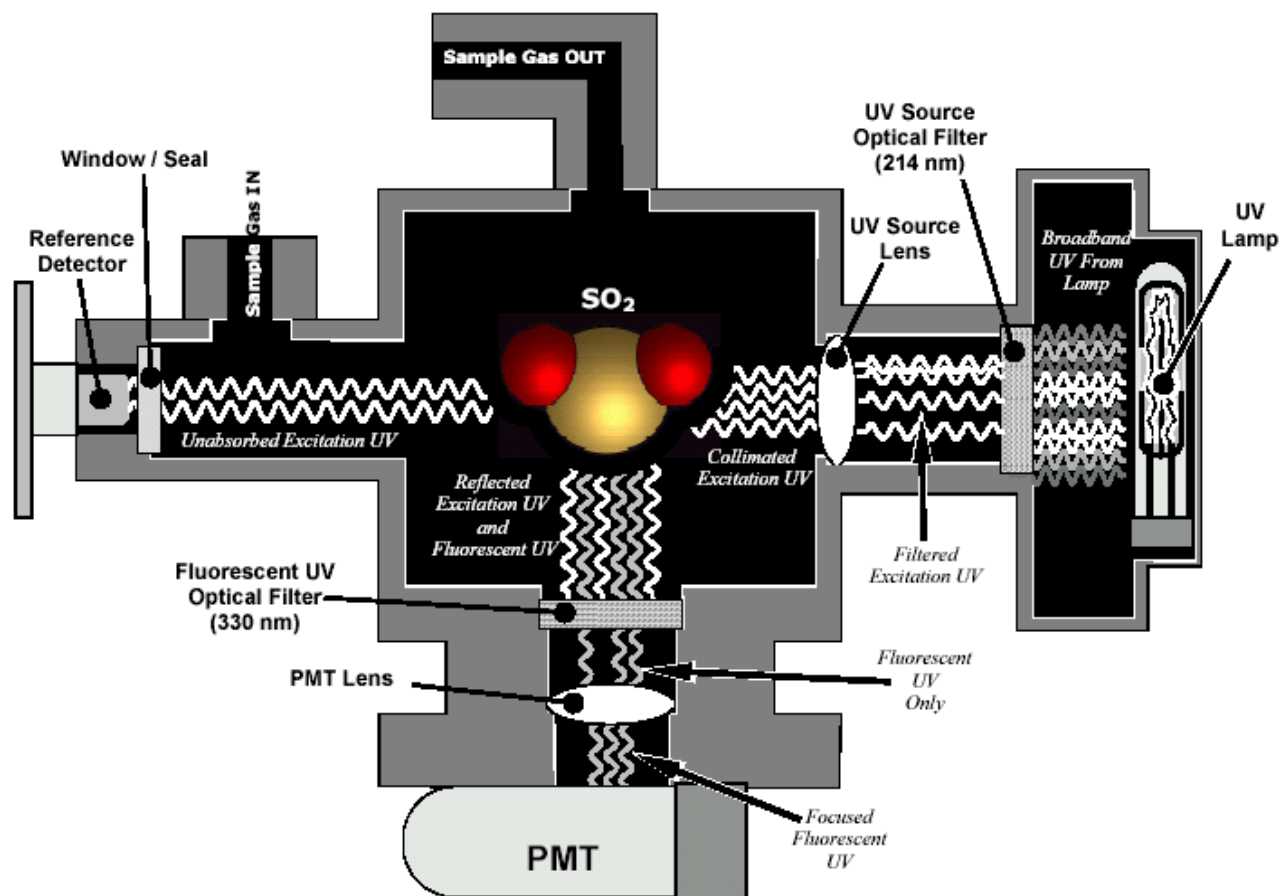
Figure 13-2:   UV Light Path

13.1.3. UV SOURCE LAMP

The source of excitation UV light for the T100 is a low pressure zinc-vapor lamp. An AC voltage heats up and vaporizes zinc contained in the lamp element creating a light-producing plasma arc. Zinc-vapor lamps are preferred over the more common mercury-vapor lamps for this application because they produce very strong emission levels at the wavelength required to convert SO_2 to SO_2*, 213.9 nm (refer to Figure 13-4).

The lamp used in the T100 is constructed with a vacuum jacket surrounding a double-bore lamp element (refer to Figure 13-3). The vacuum jacket isolates the plasma arc from most external temperature fluctuations. The jacket also contains thermal energy created by the lamp's operation therefore helping the lamp to heat up and maintain proper vaporization temperature. Light is emitted through a 20 mm x 5 mm portal.
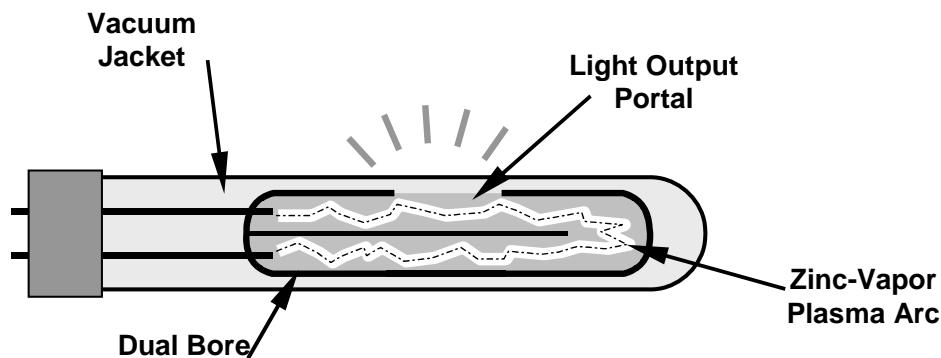
Figure 13-3: Source UV Lamp Construction

13.1.4. THE REFERENCE DETECTOR

A vacuum diode, UV detector that converts UV light to a DC current is used to measure the intensity of the excitation UV source lamp. It is located directly across from the source lamp at the back of a narrow tube-shaped light trap, which places it directly in the path of the excitation UV light. A window transparent to UV light provides an air-proof seal that prevents ambient gas from contaminating the sample chamber. The shape of the light trap and the fact that the detector is blind to wavelengths other than UV no extra optical filtering is needed.

13.1.5. THE PMT

The amount of fluoresced UV produced in the sample chamber is much less than the intensity of excitation UV source lamp (refer to Figure 13-4). Therefore a much more sensitive device is needed to detect this light with enough resolution to be meaningful. The T100 uses a Photo Multiplier Tube or PMT for this purpose.

A PMT is typically a vacuum tube containing a variety of specially designed electrodes. Photons enter the PMT and strike a negatively charged photo cathode causing it to emit electrons. These electrons are accelerated by a high voltage applied across a series of special electrodes called dynodes that multiply the amount of electrons until a useable current signal is generated. This current increases or decreases with the amount of detected light (refer to Section 13.5.3 for more details regarding the electronic operation of the PMT).

13.1.6. UV LAMP SHUTTER & PMT OFFSET

Inherent in the operation of both the reference detector and the PMT are a minor electronic offsets. The degree of offset differs from detector to detector and from PMT to PMT and can change over time as these components age.

To account for these offsets the T100 includes a shutter, located between the UV Lamp and the source filter that periodically cuts off the UV light from the sample chamber. This happens every 30 minutes. The analyzer records the outputs of both the reference detector and the PMT during this dark period and factors them into the SO_2 concentration calculation.

- The reference detector offset is stored as and viewable via the front panel as the test function **DRK LMP.**

- The PMT offset is stored as and viewable via the front panel as the test function **DRK PMT.**

13.1.7. OPTICAL FILTERS

The T100 analyzer uses two stages of optical filters to enhance performance. The first stage conditions the UV light used to excite the SO_2 by removing frequencies of light that are not needed to produce SO_2*. The second stage protects the PMT detector from reacting to light not produced by the SO_2* returning to its ground state.

13.1.7.1. UV SOURCE OPTICAL FILTER

Zinc-vapor lamps output light at other wavelengths beside the 214nm required for the $SO_2 \rightarrow SO_2*$ transformation including a relatively bright light of the same wavelength at which SO_2* fluoresces as it returns to its SO_2 ground state (330 nm). In fact, the intensity of light emitted by the UV lamp at 330nm is so bright, nearly five orders of magnitude brighter than that resulting from the SO_2* decay, it would drown out the SO_2* fluorescence.
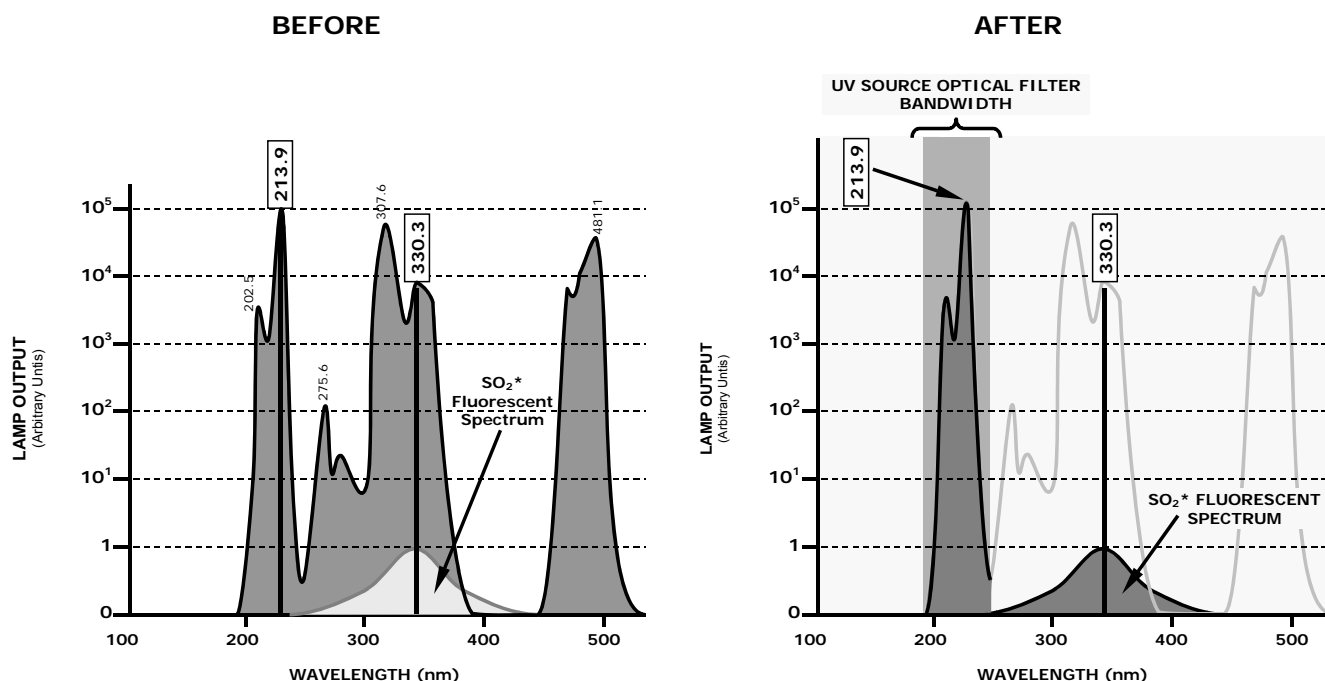
Figure 13-4:   Excitation Lamp UV Spectrum Before/After Filtration

To solve this problem, the light emitted by the excitation UV lamp passes through a band pass filter that screens out photons with wavelengths outside the spectrum required to excite SO_2 into SO_2* (refer to Figure 13-4).

13.1.7.2. **PMT OPTICAL FILTER**

The PMT used in the T100 reacts to a wide spectrum of light which includes much of the visible spectrum and most of the UV spectrum. Even though the 214 nm light used to excite the SO_2 is focused away from the PMT, some of it scatters in the direction of the PMT as it interacts with the sample gas. A second optical band pass filter placed between the sample chamber (refer to Figure 13-2) and the PMT strips away light outside of the fluorescence spectrum of decaying SO_2^* (refer to Figure 13-5) including reflected UV form the source lamp and other stray light.
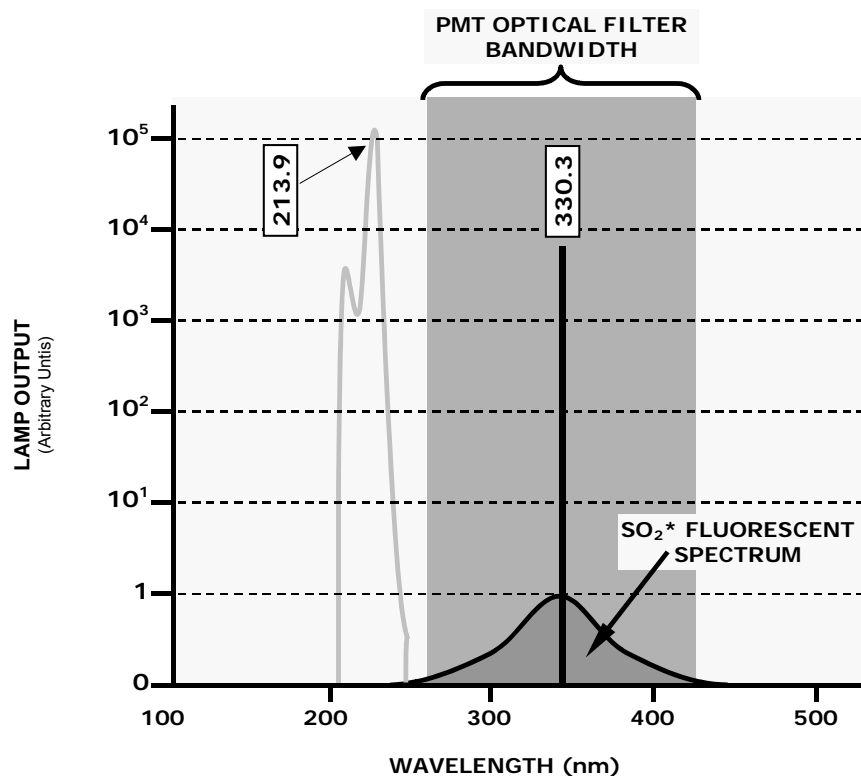
Figure 13-5: PMT Optical Filter Bandwidth

13.1.8. OPTICAL LENSES

Two optical lenses are used to focus and optimize the path of light through the sample chamber.

If source UV is unfocused, PMT receives fluorescence from area outside Reference Detector's view

When source UV is focused, PMT and Reference Detector view similar volume of SO₂*

Reference Detector

When source UV is focused, Reference Detector most of the emitted light

If source UV is unfocused, Reference Detector only sees a small portion of emitted light

UV Source Lens

214 nm Filter

330 nm Filter

PMT Lens

PMT

Figure 13-6:   Effects of Focusing Source UV in Sample Chamber

A lens located between PMT and the sample chamber collects as much of the fluoresced UV created there as possible and focuses it on the most sensitive part of the PMT's photo cathode.

Another lens located between the excitation UV source lamp and the sample chamber collimates the light emitted by the lamp into a steady, circular beam and focuses that beam directly onto the reference detector. This allows the reference detector to accurately measure the effective intensity of the excitation UV by eliminating the effect of flickering inherent in the plasma arc that generates the light.

Ensure that all of the light emitted by the source lamp, passes though the 214 nm filter and not absorbed by the SO_2 reaches the reference detector. Conversely, this also makes sure that the volume of sample gas affected by the excitation beam is similar to the volume of fluorescing SO_2* being measured by the PMT, eliminating a possible source of measurement offset.

13.1.9. MEASUREMENT INTERFERENCES

It should be noted that the fluorescence method for detecting SO_2 is subject to interference from a number of sources. The T100 has been successfully tested for its ability to reject interference from most of these sources.

13.1.9.1. DIRECT INTERFERENCE

The most common source of interference is from other gases that fluoresce in a similar fashion to SO_2 when exposed to UV Light. The most significant of these is a class of hydrocarbons called poly-nuclear aromatics (PNA) of which xylene and naphthalene are two prominent examples. Nitrogen oxide fluoresces in a spectral range near to SO_2. For critical applications where high levels of NO are expected an optional optical filter is available that improves the rejection of NO (contact Technical Support for more information).

- The T100 Analyzer has several methods for rejecting interference from these gases:

- A special scrubber (kicker) mechanism removes any PNA chemicals present in the sample gas before it the reach the sample chamber.

- The exact wavelength of light needed to excite a specific non-SO_2 fluorescing gas is removed by the source UV optical filter.

- The light given off by Nitrogen Oxide and many of the other fluorescing gases is outside of the bandwidth passed by the PMT optical filter.

13.1.9.2. UV ABSORPTION BY OZONE

Because ozone absorbs UV Light over a relatively broad spectrum it could cause a measurement offset by absorbing some of the UV given off by the decaying SO_2* in the sample chamber. The T100 prevents this from occurring by having a very short light path between the area where the SO_2* fluorescence occurs and the PMT detector. Because the light path is so short, the amount of O_3 needed to cause a noticeable effect would be much higher than could be reasonably expected in any application for which this instrument is intended.

13.1.9.3. DILUTION

Certain gases with higher viscosities can lower the flow rate though the critical flow orifice that controls the movement of sample gas though the analyzer reducing the amount of sample gas in the sample chamber and thus the amount of SO_2 available to react with the to the UV light. While this can be a significant problem for some analyzers, the design of the T100 is very tolerant of variations in sample gas flow rate and therefore does not suffer from this type of interference.

13.1.9.4. THIRD BODY QUENCHING

While the decay of SO_2* to SO_2 happens quickly, it is not instantaneous. Because it is not instantaneous it is possible for the extra energy possessed by the excited electron of the SO_2* molecule to be given off as kinetic energy during a collision with another molecule. This in effect heats the other molecule slightly and allows the excited electron to move into a lower energy orbit without emitting a photon.

The most significant interferents in this regard are nitrogen oxide (NO), carbon dioxide (CO_2), water vapor (H_2O) and molecular oxygen (O_2). In ambient applications the quenching effect of these gases is negligible. For stack applications where the

concentrations of some or all of these may be very high, specific steps MUST be taken to remove them from the sample gas before it enters the analyzer.

13.1.9.5. **LIGHT POLLUTION**

Because T100 measures light as a means of calculating the amount of SO_2 present, obviously stray light can be a significant interfering factor. The T100 removes this interference source in several ways.

- The sample chamber is designed to be completely light tight to light from sources other than the excitation UV source lamp.

- All pneumatic tubing leading into the sample chamber is completely opaque in order to prevent light from being piped into the chamber by the tubing walls.

- The optical filters discussed in Section 13.1.7; remove UV with wavelengths extraneous to the excitation and decay of SO_2/SO_2*.

- Most importantly, during instrument calibration the difference between the value of the most recently recorded PMT offset (refer to Section 13.1.6) and the PMT output while measuring zero gas (calibration gas devoid of SO_2) is recorded as the test function **OFFSET**. This **OFFSET** value is used during the calculation of the SO_2 concentration.

Since this offset is assumed to be due to stray light present in the sample chamber is also multiplied by the **SLOPE** and recorded as the function **STR. LGT**. Both **OFFSET & STR. LGT** are viewable via the front panel (refer to Section 4.1.1).

13.2. OXYGEN (O₂) SENSOR PRINCIPLES OF OPERATION

The O_2 sensor applies paramagnetics to determine the concentration of oxygen in a sample gas drawn through the instrument.

13.2.1. PARAMAGNETIC MEASUREMENT OF O₂

The oxygen sensor used in the T100 utilizes the fact that oxygen is attracted into strong magnetic field while most other gases are not, to obtain fast, accurate oxygen measurements.

The sensor's core is made up of two nitrogen filled glass spheres, which are mounted on a rotating suspension within a magnetic field (refer to Figure 13-7). A mirror is mounted centrally on the suspension and light is shone onto the mirror that reflects the light onto a pair of photocells. The signal generated by the photocells is passed to a feedback loop, which outputs a current to a wire winding (in effect, a small DC electric motor) mounted on the suspended mirror.

Oxygen from the sample stream is attracted into the magnetic field displacing the nitrogen filled spheres and causing the suspended mirror to rotate. Therefore, the amount of light reflected onto the photocells and therefore the output levels of the photocells. The feedback loop increases the amount of current fed into the winding in order to move the mirror back into its original position. The more O_2 present, the more the mirror moves and the more current is fed into the winding by the feedback control loop.

A sensor measures the amount of current generated by the feedback control loop which is directly proportional to the concentration of oxygen within the sample gas mixture.
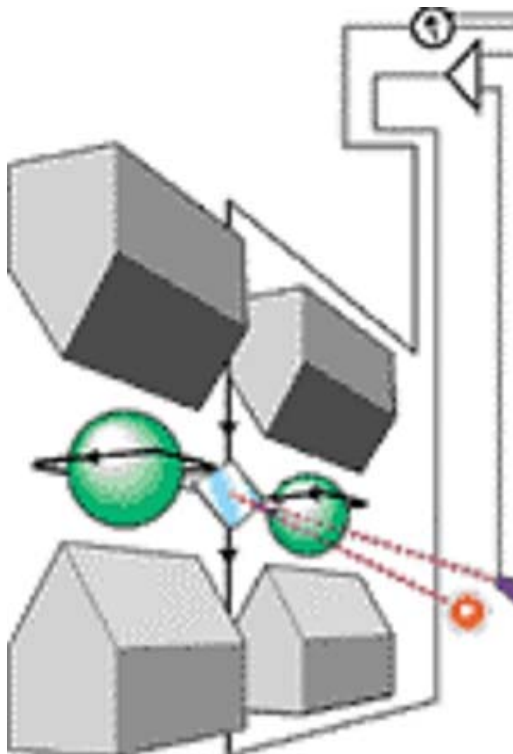
Figure 13-7:   Oxygen Sensor - Principles of Operation

13.2.2. O$_2$ SENSOR OPERATION WITHIN THE T100 ANALYZER

The oxygen sensor option is transparently integrated into the core analyzer operation. All functions can be viewed or accessed through the front panel display, just like the functions for SO$_2$.

- The O$_2$ concentration is displayed below the SO$_2$ concentration.

- Test functions for O$_2$ slope and offset are viewable from the front panel along with the other test functions of the analyzer.

- O$_2$ sensor calibration is performed via the front panel **CAL** function and is performed in a nearly identical manner as the standard SO$_2$ calibration. Refer to Section 9.10.1 for more details.

- Stability of the O$_2$ sensor can be viewed via the front panel (refer to Section 9.10.1.3).

The O$_2$ concentration range is 0-100% (user selectable) with 0.1% precision and accuracy.

The temperature of the O$_2$ sensor is maintained at a constant 50°C by means of a PID loop and can be viewed on the front panel as test function O$_2$ TEMP.

The O$_2$ sensor assembly itself does not have any serviceable parts and is enclosed in an insulated canister.

13.3. CARBON DIOXIDE (CO_2) SENSOR PRINCIPLES OF OPERATION

The CO_2 sensor probe measures the concentration of carbon dioxde in the sample gas; a Logic PCA conditions the probe output and issues a 0-5 VDC signal to the analyzer's CPU, which computes the CO_2 concentration by scaling the values of the CO_2_**SLOPE** and CO_2_**OFFSET** recorded during calibration

The CO_2 sensor assembly itself does not have any serviceable parts and is enclosed in an insulated canister.

13.3.1. NDIR MEASUREMENT OF CO_2

The optional CO_2 sensor is a silicon based Non-Dispersive Infrared (NDIR) sensor. It uses a single-beam, dual wavelength measurement method.

An infrared source at one end of the measurement chamber emits IR radiation into the sensor's measurement chamber where light at the 4.3 μm wavelength is partially absorbed by any CO_2 present. A special light filter called a Fabry-Perot Interferometer (FPI) is electronically tuned so that only light at the absorption wavelength of CO_2 is allowed to pass and be detected by the sensor's IR detector.

A reference measurement is made by electronically shifting the filter band pass wavelength so that no IR at the CO_2 absorption wavelength is let through.
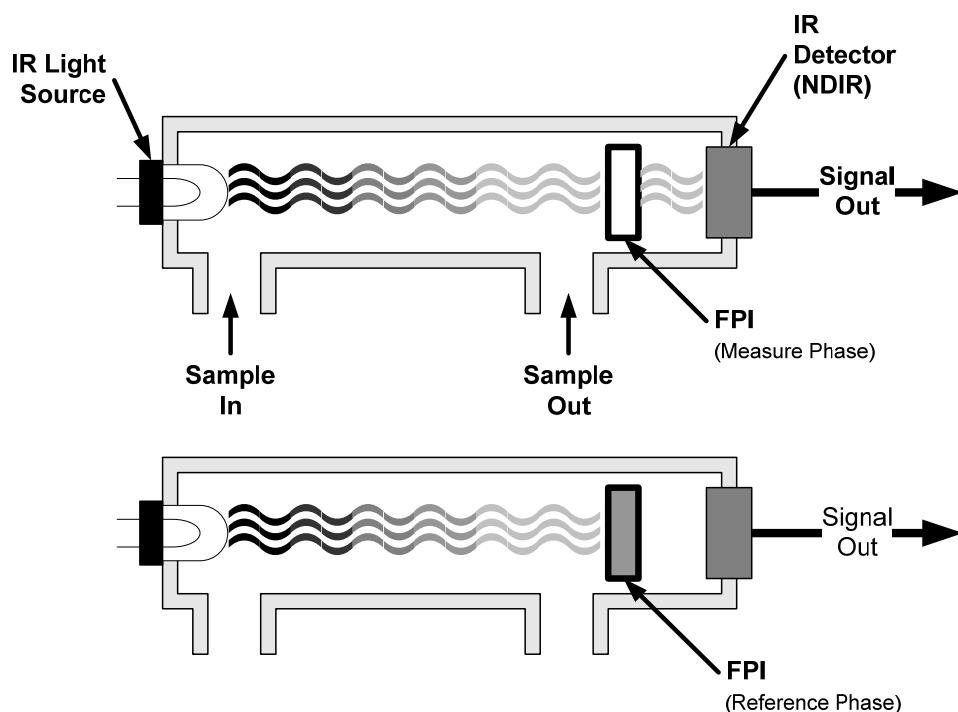
Figure 13-8: CO_2 Sensor Principles of Operation

The sensor computes the ratio between the reference signal and the measurement signal to determine the degree of light absorbed by CO_2 present in the sensor chamber. This dual wavelength method the CO_2 measurement allows the instrument to compensate for ancillary effects like sensor aging and contamination.

13.3.2. CO$_2$ OPERATION WITHIN THE T100 ANALYZER

The CO2 sensor option is transparently integrated into the core analyzer operation. All functions can be viewed or accessed through the front panel display, just like the functions for SO$_2$.

- The CO$_2$ concentration is displayed below the SO$_2$ concentration.

- Test functions for CO$_2$ slope and offset are viewable from the front panel along with the other test functions of the analyzer.

- CO$_2$ sensor calibration is performed via the front panel **CAL** function and is performed in a nearly identical manner as the standard SO$_2$ calibration.

- Stability of the CO$_2$ sensor can be viewed via the front panel (refer to Section 9.10.2.3).

Refer to Section 3.4.4.3 for information on calibrating the CO$_2$.

13.3.3. ELECTRONIC OPERATION OF THE CO$_2$ SENSOR

The CO$_2$ PCA, which is mounted to the rear side of the Relay Board Mounting Bracket, controls the CO$_2$ sensor. It converts the sensor's digital output to an analog voltage that is measured with the motherboard and draws 12 VDC from the analyzer via the relay card from which converts to fit the power needs of the probe and its own onboard logic. It outputs a 0-5 VDC analog signal to the analyzer's CPU via the motherboard that corresponds to the concentration of CO$_2$ measured by the probe.
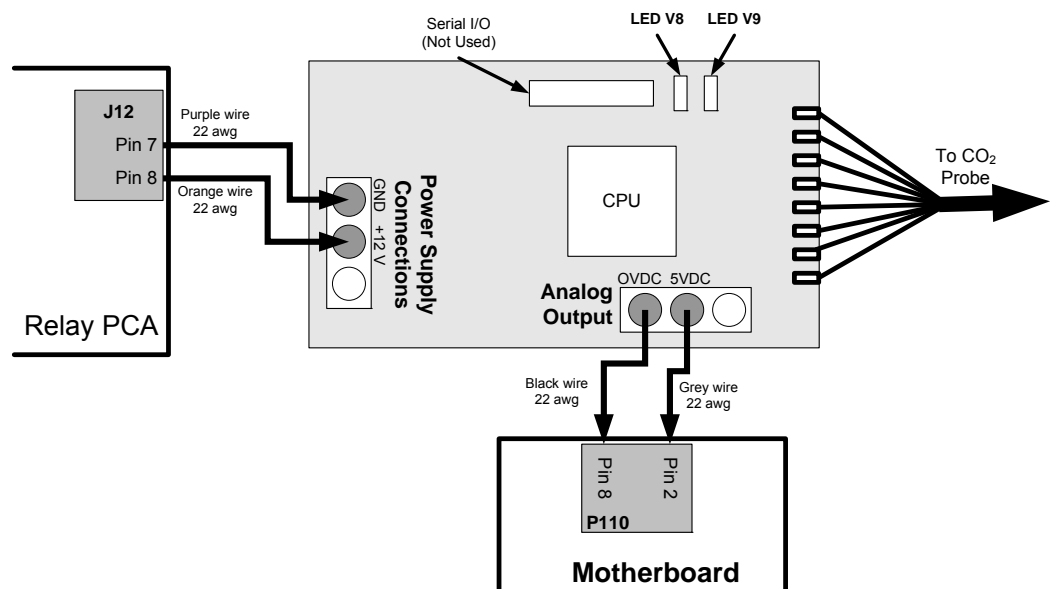
Figure 13-9:   CO2 Sensor Option PCA Layout and Electronic Connections

13.4. PNEUMATIC OPERATION

13.4.1. SAMPLE GAS FLOW

The Flow of gas through the T100 UV Fluorescence SO_2 Analyzer is created by a small internal pump that pulls air though the instrument.
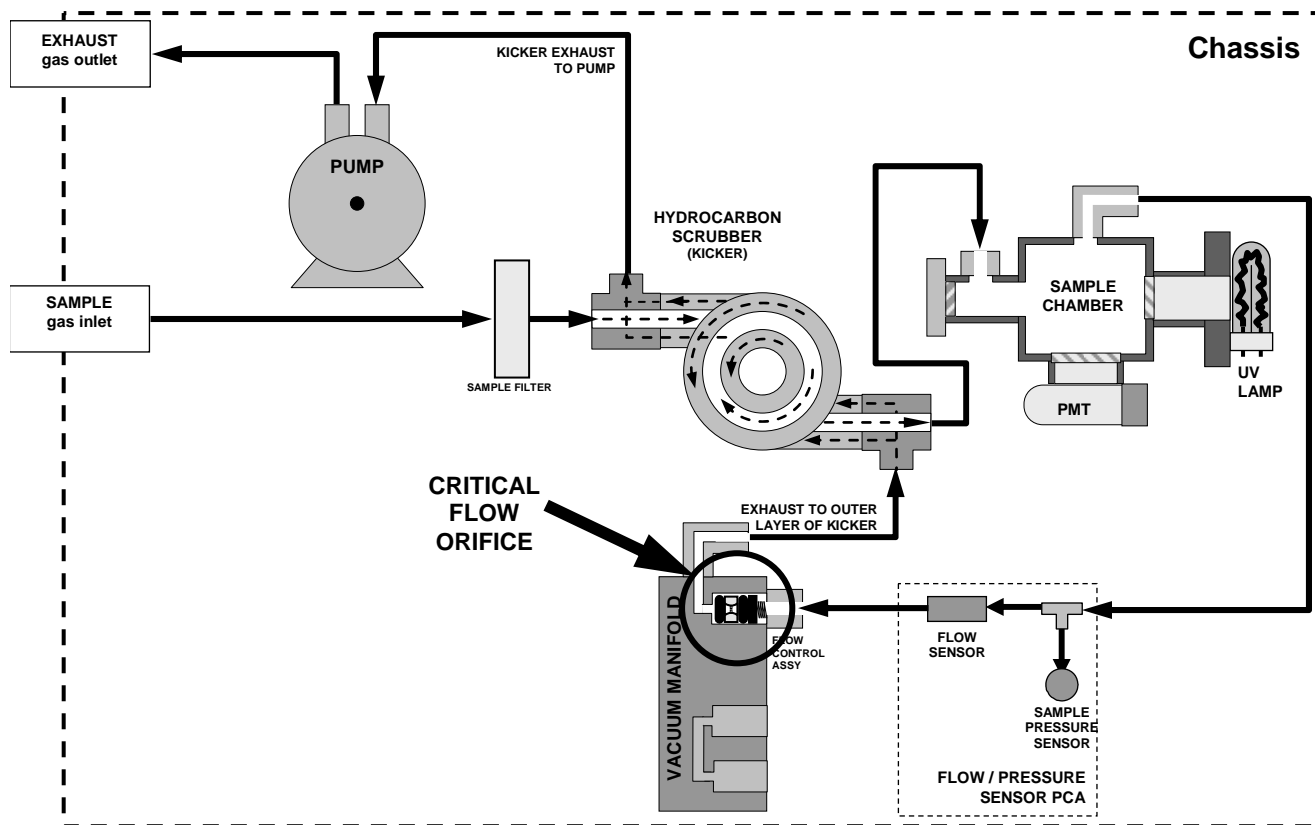
Figure 13-10:   Gas Flow and Location of Critical Flow Orifice

13.4.2. FLOW RATE CONTROL

The T100 uses a special flow control assembly located in the exhaust vacuum manifold (refer to Figure 13-10) to maintain a constant flow rate of the sample gas through the instrument. This assembly consists of:

- A critical flow orifice.

- Two o-rings: Located just before and after the critical flow orifice, the o-rings seal the gap between the walls of assembly housing and the critical flow orifice.

- A spring: Applies mechanical force needed to form the seal between the o-rings, the critical flow orifice and the assembly housing.

13.4.2.1. CRITICAL FLOW ORIFICE

The most important component of this flow control assembly is the critical flow orifice.

Critical flow orifices are a simple way to regulate stable gas flow rates. They operate without moving parts by taking advantage of the laws of fluid dynamics. Restricting the flow of gas though the orifice creates a pressure differential. This pressure differential combined with the action of the analyzer's pump draws the gas through the orifice.

As the pressure on the downstream side of the orifice (the pump side) continues to drop, the speed that the gas flows though the orifice continues to rise. Once the ratio of upstream pressure to downstream pressure is greater than 2:1, the velocity of the gas through the orifice reaches the speed of sound. As long as that ratio stays at least 2:1 the gas flow rate is unaffected by any fluctuations, surges, or changes in downstream pressure because such variations only travel at the speed of sound themselves and are therefore cancelled out by the sonic shockwave at the downstream exit of the critical flow orifice.
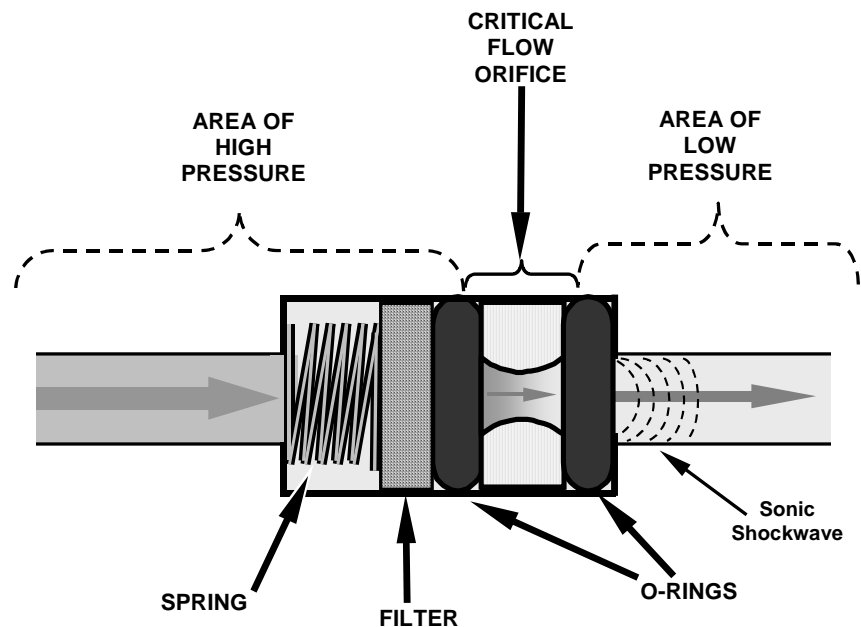
Figure 13-11:   Flow Control Assembly & Critical Flow Orifice

The actual flow rate of gas through the orifice (volume of gas per unit of time), depends on the size and shape of the aperture in the orifice. The larger the hole, the more gas molecules, moving at the speed of sound, pass through the orifice. Because the flow rate of gas through the orifice is only related to the minimum 2:1 pressure differential and not absolute pressure the flow rate of the gas is also unaffected by degradations in pump efficiency due to age.

The critical flow orifice used in the T100 is designed to provide a flow rate of 650 cm^3/min.

13.4.2.2. SAMPLE PARTICULATE FILTER

To remove particles in the sample gas, the analyzer is equipped with a Teflon membrane filter of 47 mm diameter (also referred to as the sample filter) with a 1 µm pore size. The filter is accessible through the front panel, which folds down, and should be changed according to the suggested maintenance schedule listed in Table 11-1.

13.4.3. HYDROCARBON SCRUBBER (KICKER)

It is very important to ensure that the air supplied sample chamber is clear of hydrocarbons. To accomplish this task the T100 uses a single tube permeation scrubber. The scrubber consists of a single tube of a specialized plastic that absorbs hydrocarbons very well. This tube is located within outer flexible plastic tube shell. As gas flows through the inner tube, hydrocarbons are absorbed into the membrane walls and transported through the membrane wall and into the hydrocarbon free, purge gas flowing through the outer tube. This process is driven by the hydrocarbon concentration gradient between the inner and outer of the tubes.
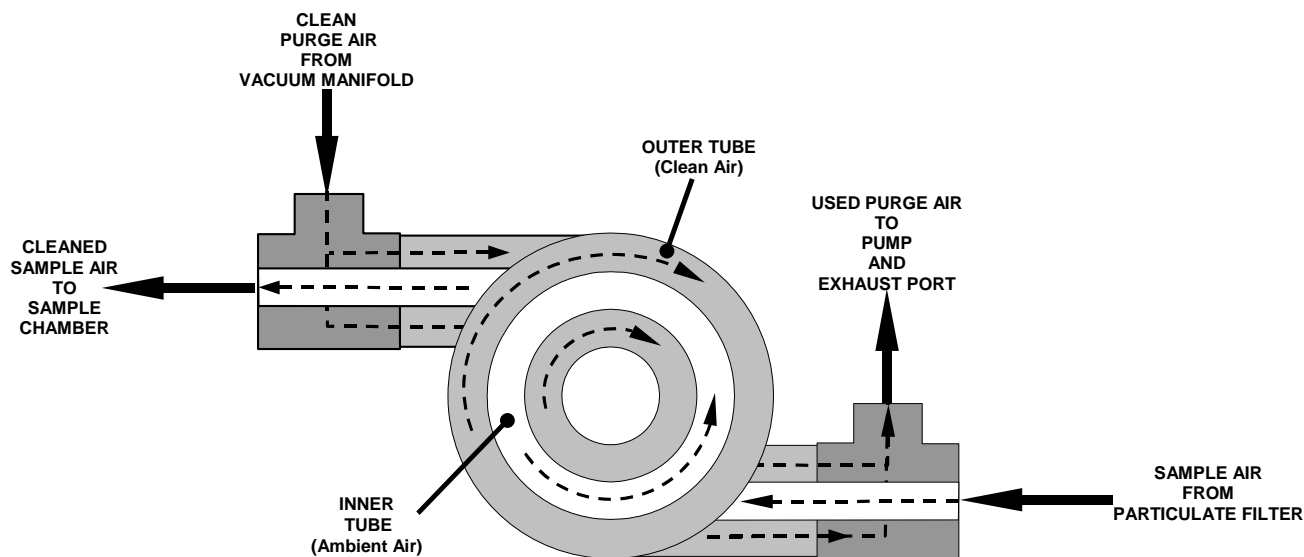
Figure 13-12:   T100 Hydrocarbon Scrubber (Kicker)

In the T100 some of the cleaned air from the inner tube is returned to be used as the purge gas in the outer tube (refer to Figure 13-12). This means that when the analyzer is first started, the concentration gradient between the inner and outer tubes is not very large and the scrubber's efficiency is relatively low. When the instrument is turned on after having been off for more than 30 minutes, it takes a certain amount of time for the gradient to become large enough for the scrubber to adequately remove hydrocarbons from the sample air.

13.4.4. PNEUMATIC SENSORS

The T100 uses two pneumatic sensors to verify gas streams. These sensors are located on a printed circuit assembly, called the pneumatic pressure/flow sensor board. The flow simultaneously enters the sample pressure sensor and the flow sensor from the outlet of the reaction cell.

13.4.4.1. SAMPLE PRESSURE SENSOR

An absolute pressure transducer plumbed to the input of the analyzer's sample chamber is used to measure the pressure of the sample gas before it enters the chamber. This upstream used to validate the critical flow condition (2:1 pressure ratio) through the instrument's critical flow orifice (refer to Section 13.4.2). Also, if the Temperature/Pressure Compensation (TPC) feature is turned on (refer to Section 13.7.3), the output of this sensor is also used to supply pressure data for that calculation.

The actual pressure measurement is viewable through the analyzer's front panel display as the test function **PRESS**.

13.4.4.2. SAMPLE FLOW SENSOR

A thermal-mass flow sensor is used to measure the sample flow through the analyzer. This sensor is also mounted on the pneumatic pressure/flow sensor board upstream of the sample chamber. The flow rate is monitored by the CRT which issues a warning message (**SAMP FLOW WARN**) if the flow rate is too high or too low.

The flow rate of the sample gas is viewable via the front panel as the **SAMP FL** test function.

13.5. ELECTRONIC OPERATION
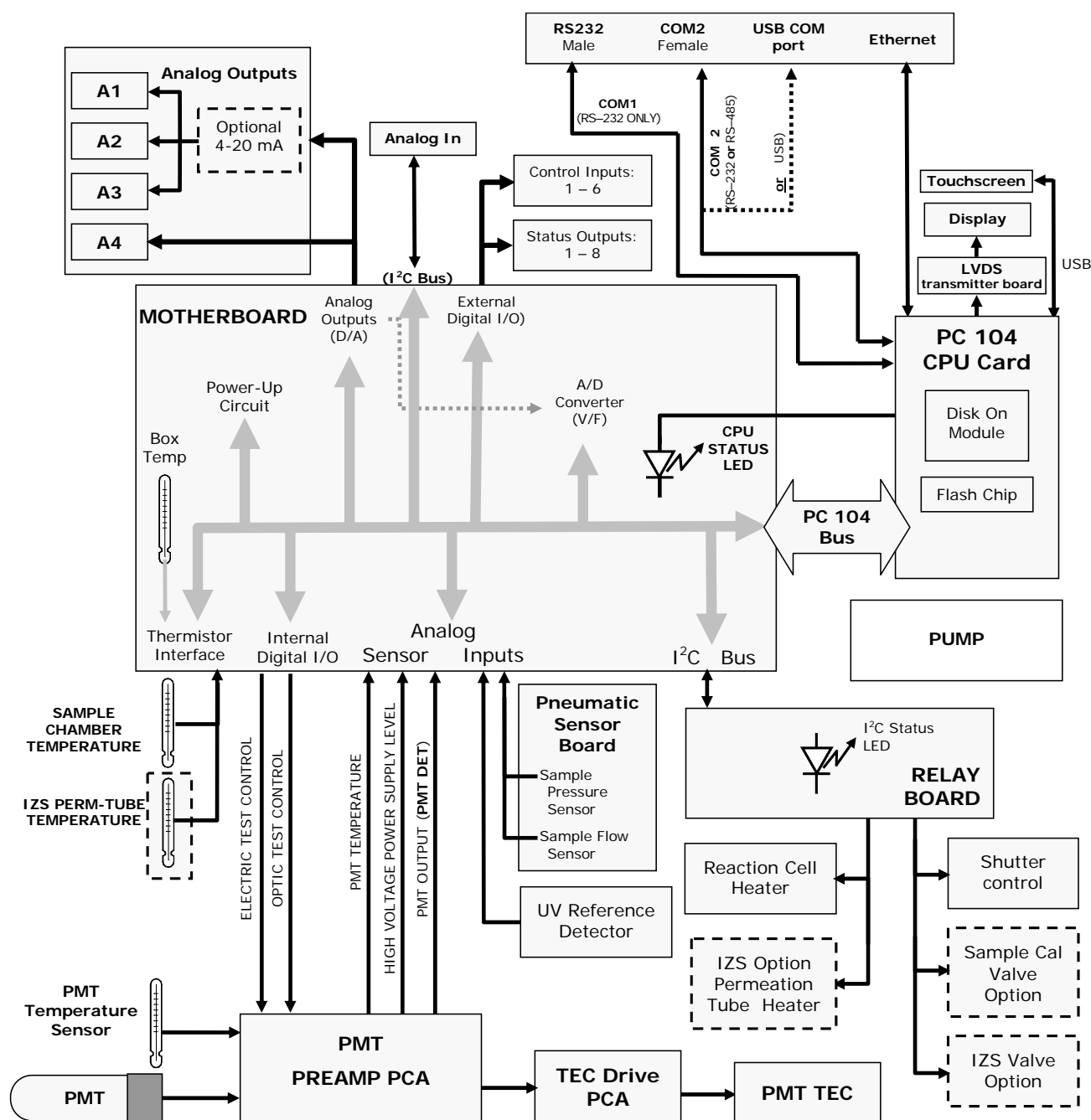
Figure 13-13:   T100 Electronic Block Diagram

The core of the analyzer is a microcomputer that controls various internal processes, interprets data, makes calculations, and reports results using specialized firmware developed by Teledyne API. It communicates with the user as well as receives data from and issues commands to a variety of peripheral devices through a separate printed circuit assembly to which the CPU is mounted: the motherboard.

The motherboard is directly mounted to the rear panel and collects data, performs signal conditioning duties and routes incoming and outgoing signals between the CPU and the analyzer's other major components.

Concentration data of the T100 are generated by the Photo Multiplier Tube (PMT), which produces an analog current signal corresponding to the brightness of the fluorescence reaction in the sample chamber. This current signal is amplified to a DC voltage signal (front panel test parameter **PMT**) by a PMT preamplifier printed circuit assembly (located on top of the sensor housing). **PMT** is converted to digital data by a bi-polar, analog-to-digital converter, located on the motherboard.

In addition to the PMT signal, a variety of sensors report the physical and operational status of the analyzer's major components, again through the signal processing capabilities of the motherboard. These status reports are used as data for the SO_2 concentration calculation (e.g. pressure and temperature reading used by the temperature/pressure compensation feature) and as trigger events for certain warning messages and control commands issued by the CPU. They are stored in the CPU's memory and, in most cases, can be viewed through the front panel display.

The CPU communicates with the user and the outside world in a variety of ways:

- Through the analyzer's front panel LCD touch-screen interface
- RS-232 and RS-485 serial I/O channels
- Various analog voltage and current outputs
- Several digital I/O channels
- Ethernet

Finally, the CPU issues commands (also over the I^2C bus) to a series of relays and switches located on a separate printed circuit assembly, the relay board (located in the rear of the chassis on its own mounting bracket) to control the function of key electromechanical devices such as valves and heaters.

13.5.1. CPU

The unit's CPU card, installed on the motherboard located inside the rear panel, is a low power (5 VDC, 720mA max), high performance, Vortex 86SX-based microcomputer running Windows CE. Its operation and assembly conform to the PC 104 specification..
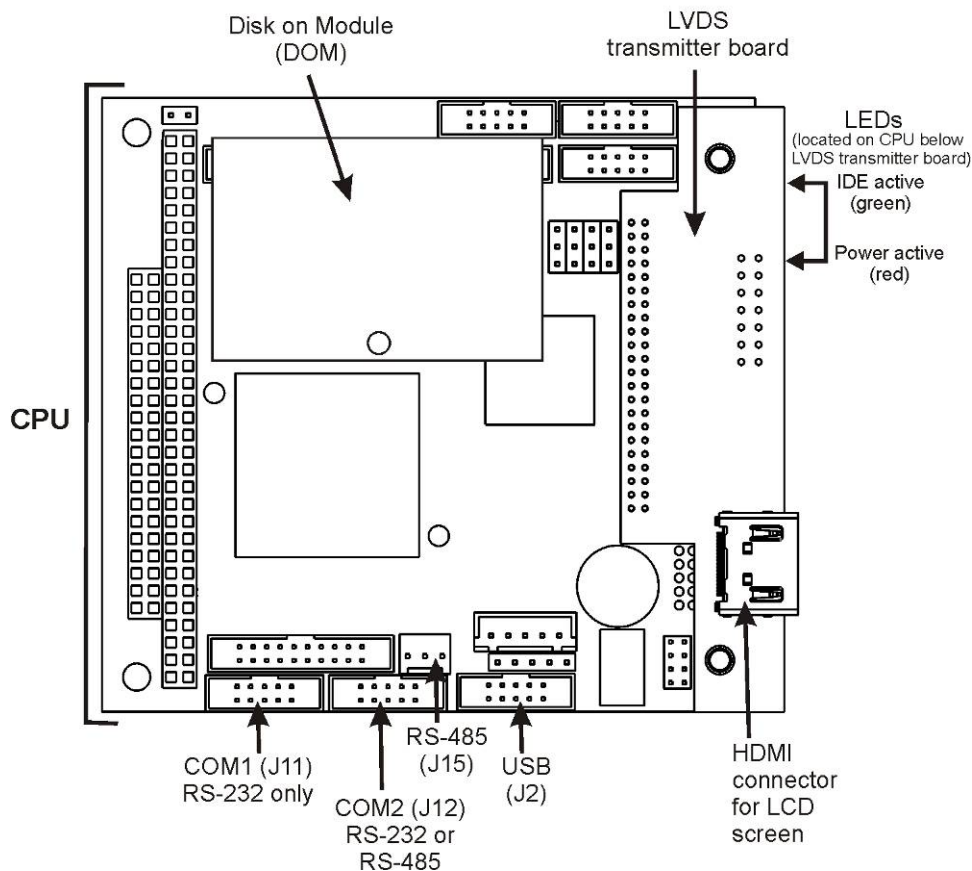
Figure 13-14:   CPU Board Annotated

The CPU includes two types of non-volatile data storage: a Disk on Module (DOM) and an embedded flash chip.

13.5.1.1. DISK ON MODULE (DOM)

The DOM is a 44-pin IDE flash chip with storage capacity to 256 MB. It is used to store the computer's operating system, the Teledyne API firmware, and most of the operational data generated by the analyzer's internal data acquisition system (DAS). Embedded in the DOM is a flash chip.

13.5.1.2. FLASH CHIP

This non-volatile, embedded flash chip includes 2MB of storage for calibration data as well as a backup of the analyzer configuration. Storing these key data onto a less heavily accessed chip significantly decreases the chance data corruption.

In the unlikely event that the flash chip should fail, the analyzer will continue to operate with just the DOM. However, all configuration information will be lost, requiring that the unit be recalibrated.

13.5.2. SENSOR MODULE

Electronically, the T100 sensor module is a group of components that: create the UV light that initiates the fluorescence reaction between SO_2 and O_3; sense the intensity of that fluorescence; generate various electronic signals needed by the analyzer to determine the SO_2 concentration of the sample gas (refer to Section 13.1.1), and sense and control key environmental conditions such as the temperature of the sample gas and the PMT.
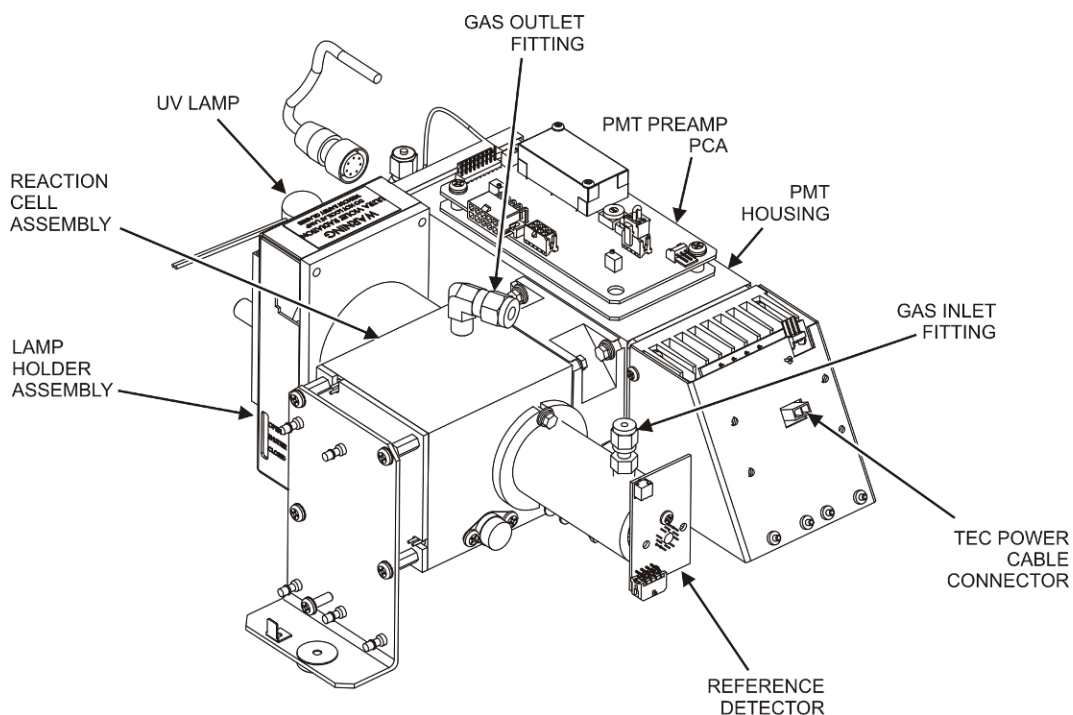
Figure 13-15:   T100 Sensor Module

These components are divided into two significant subassemblies: the sample chamber and the PMT assembly.

Figure 13-16 shows an exploded view of the sample chamber assembly

Figure 13-17shows an exploded view of the PMT Assembly

13.5.2.1. SAMPLE CHAMBER

The main electronic components of the sample chamber are the reference detector (refer to Section 13.1.4); the UV Lamp (refer to Section 13.1.3) and its electronically operated shutter (refer to Section 13.1.6); and the sample chamber heating circuit.
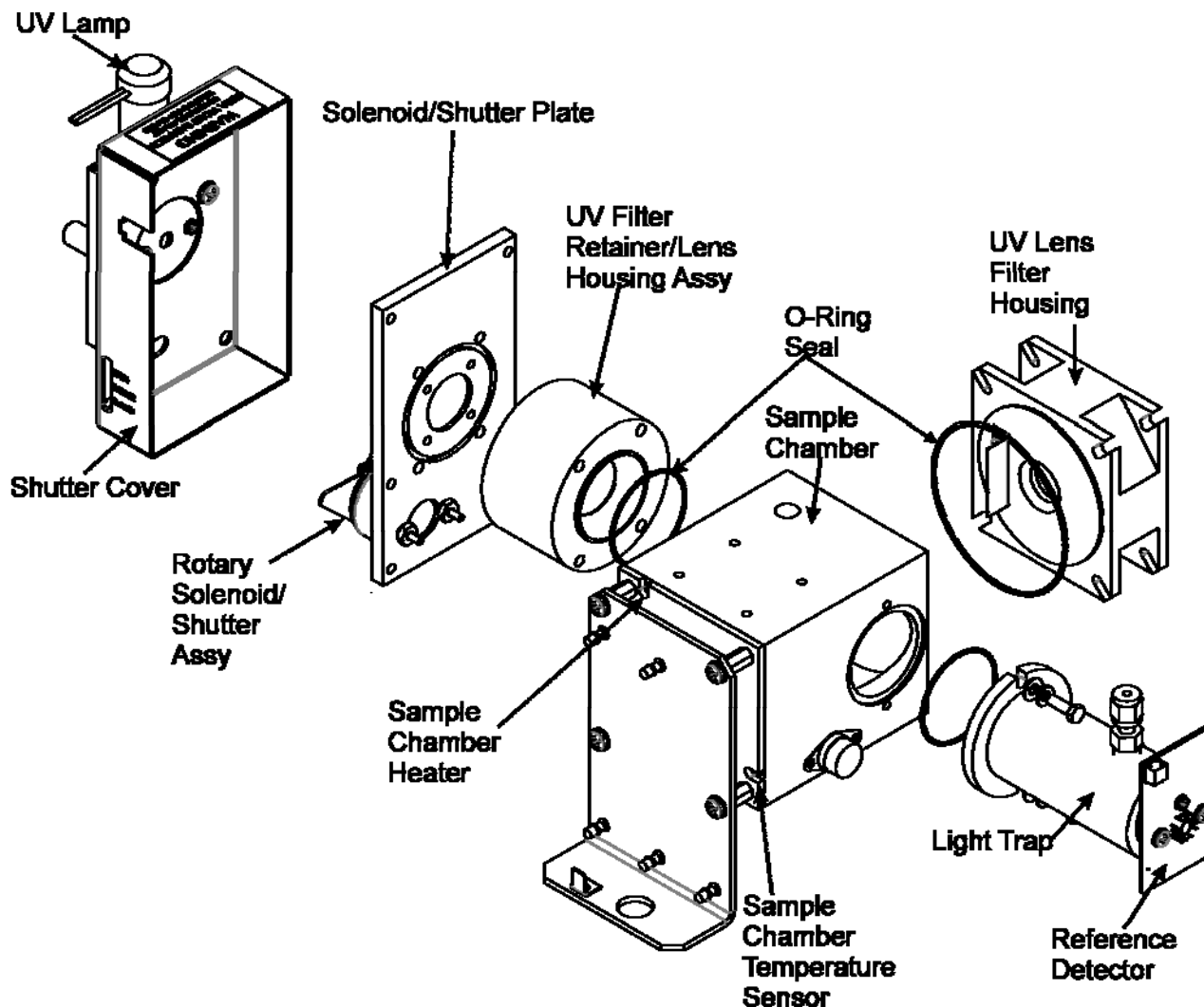
Figure 13-16:   T100 Sample Chamber

13.5.2.2. SAMPLE CHAMBER HEATING CIRCUIT

In order to reduce temperature effects, the sample chamber is maintained at a constant 50°C, just above the high end of the instrument's operation temperature range. Two AC heaters, one embedded into the top of the sample chamber, the other embedded directly below the reference detector's light trap, provide the heat source. These heaters operate off of the instrument's main AC power and are controlled by the CPU through a power relay on the relay board. A thermistor, also embedded in the bottom of the sample chamber, reports the cell's temperature to the CPU through the thermistor interface circuitry of the motherboard.

13.5.3. PHOTO MULTIPLIER TUBE (PMT)

The T100 uses a photo multiplier tube (PMT) to detect the amount of fluorescence created by the SO_2 and O_3 reaction in the sample chamber.
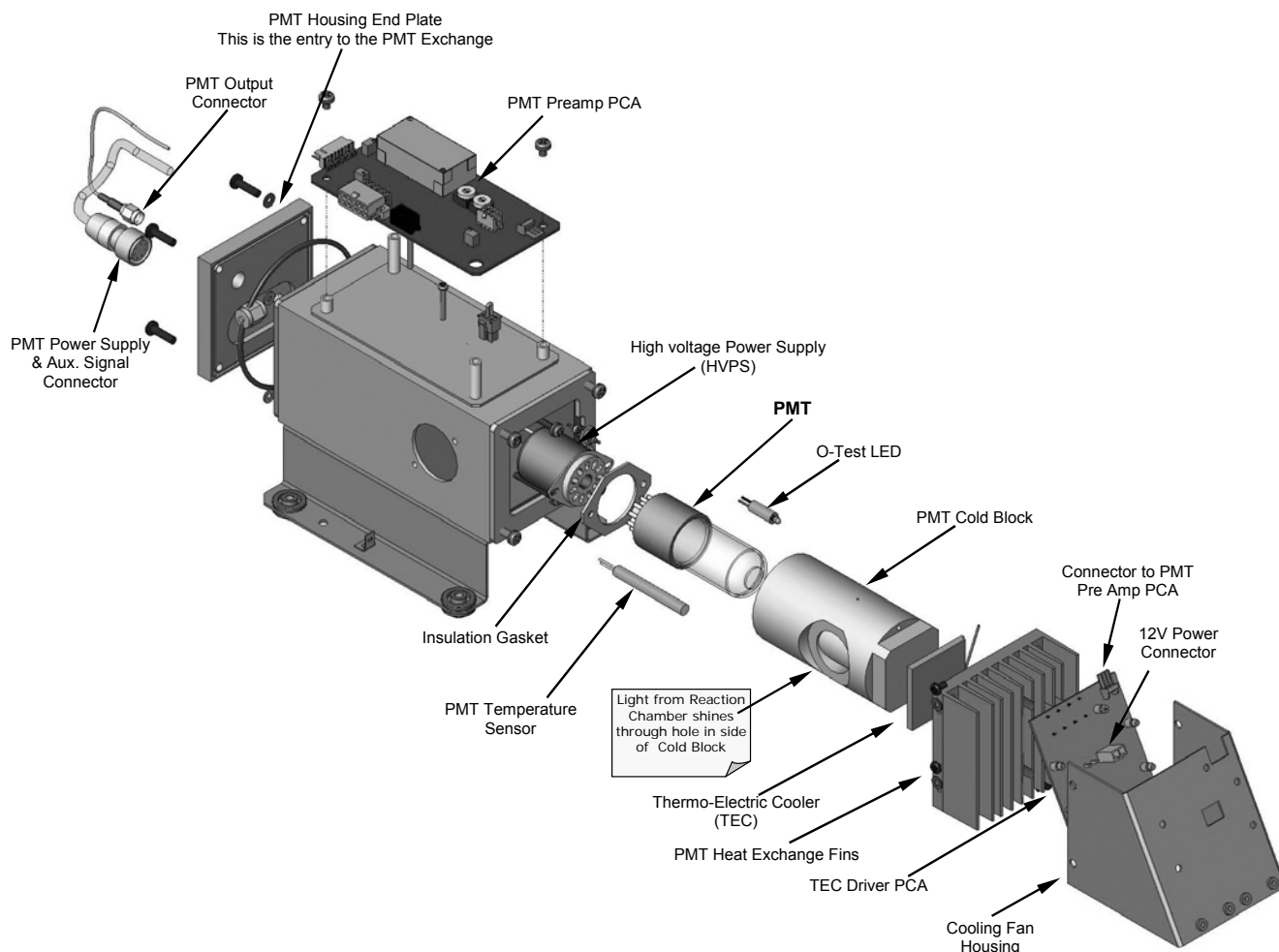
Figure 13-17:　PMT Housing Assembly

A typical PMT is a vacuum tube containing a variety of specially designed electrodes. Photons from the reaction are filtered by an optical high-pass filter, enter the PMT and strike a negatively charged photo cathode causing it to emit electrons. A high voltage potential across these focusing electrodes directs the electrons toward an array of high voltage dynodes. The dynodes in this electron multiplier array are designed so that each stage multiplies the number of emitted electrons by emitting multiple, new electrons. The greatly increased number of electrons emitted from one end of electron multiplier is collected by a positively charged anode at the other end, which creates a useable current signal. This current signal is amplified by the preamplifier board and then reported to the motherboard.
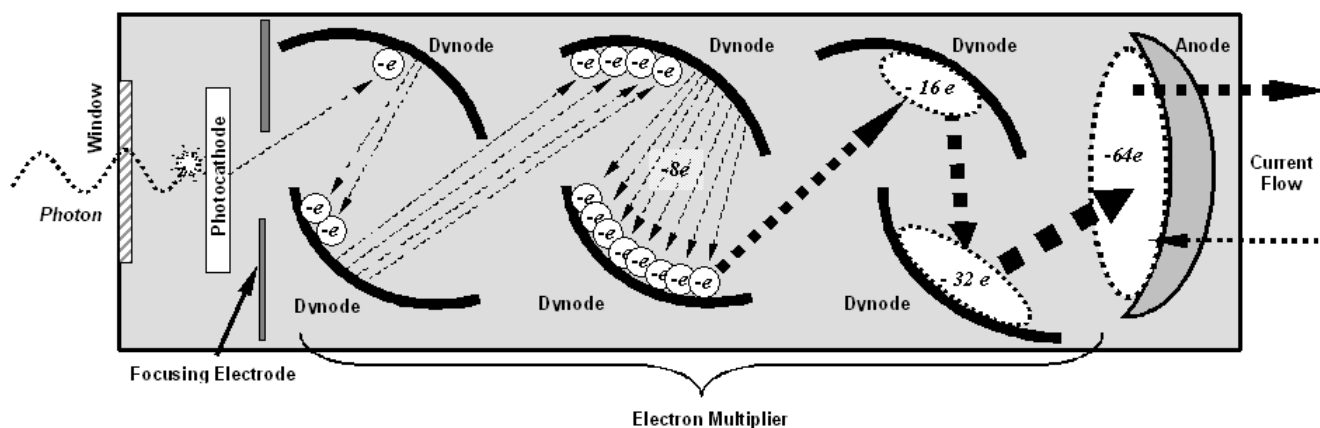
Figure 13-18: Basic PMT Design

A significant performance characteristic of the PMT is the voltage potential across the electron multiplier. The higher the voltage, the greater is the number of electrons emitted from each dynode of the electron multiplier, making the PMT more sensitive and responsive to small variations in light intensity but also more noisy (dark noise). The gain voltage of the PMT used in the T100 is usually set between 450 V and 800 V. This parameter is viewable through the front panel as test function **HVPS** (refer to Section 4.1.1). For information on when and how to set this voltage, refer to Section 12.7.2.8.

The PMT is housed inside the PMT module assembly (refer to Figure 13-15 and Figure 13-17). This assembly also includes the high voltage power supply required to drive the PMT, an LED used by the instrument's optical test function, a thermistor that measures the temperature of the PMT and various components of the PMT cooling system including the Thermo-Electric Cooler (TEC).

13.5.4. PMT COOLING SYSTEM

The performance of the analyzer's PMT is significantly affected by temperature. Variations in PMT temperature are directly reflected in the signal output of the PMT. Also the signal to noise ratio of the PMT output is radically influenced by temperature as well. The warmer The PMT is, the noisier its signal becomes until the noise renders the concentration signal useless. To alleviate this problem a special cooling system exists that maintains the PMT temperature at a stable, low level.
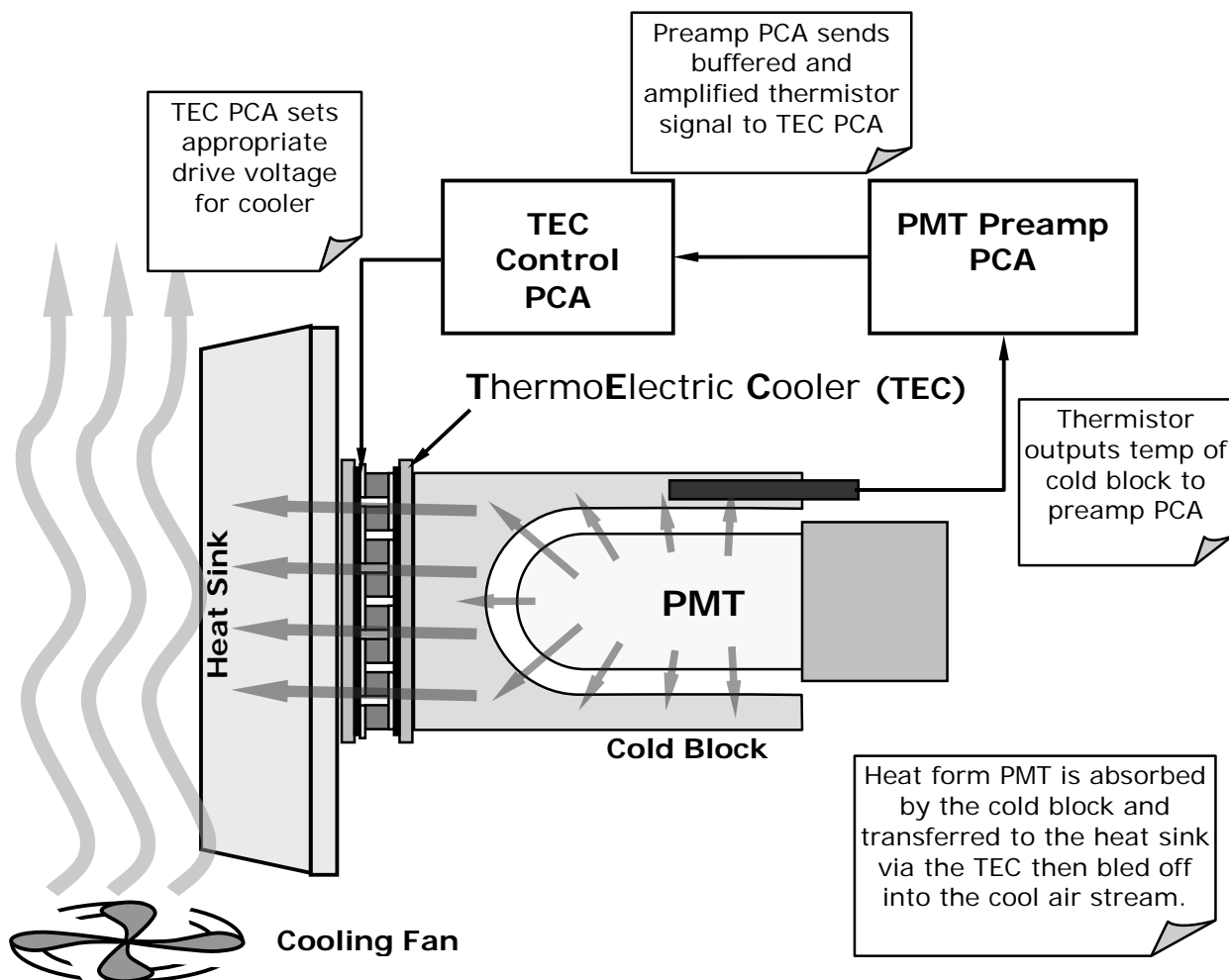
Figure 13-19:   PMT Cooling System

13.5.4.1. **THERMOELECTRIC COOLER (TEC)**

The core of the T100 PMT cooling system is a solid state heat pump called a thermoelectric cooler (TEC). Thermoelectric coolers transfer heat from a one side of a special set of semiconductor junctions to the other when a DC current is applied. The heat is pumped at a rate proportional to the amount of current applied. In the T100 the TEC is physically attached to a cold block that absorbs heat directly from the PMT and a heat sink that is cooled by moving air (refer to Figure 13-19). A Thermocouple embedded into the cold block generates an analog voltage corresponding to the current temperature of the PMT. The PMT Preamp PCA conditions and amplifies this signal then passes it on to the TEC Control PCA.

13.5.4.2. **TEC CONTROL BOARD**

The TEC control printed circuit assembly is located ion the sensor housing assembly, under the slanted shroud, next to the cooling fins and directly above the cooling fan. Using the amplified PMT temperature signal from the PMT preamplifier board (refer to Section 13.5.5), it sets the drive voltage for the thermoelectric cooler. The warmer the PMT gets, the more current is passed through the TEC causing it to pump more heat to the heat sink.

A red LED located on the top edge of this circuit board indicates that the control circuit is receiving power. Four test points are also located at the top of this assembly. For the definitions and acceptable signal levels of these test points refer to Section 12.1.2.

13.5.5. PMT PREAMPLIFIER

The PMT preamplifier board amplifies the PMT signal into a useable analog voltage that can be processed by the motherboard into a digital signal to be used by the CPU to calculate the SO_2 concentration of the gas in the sample chamber.

The output signal of the PMT is controlled by two different adjustments. First, the voltage across the electron multiplier array of the PMT is adjusted with a set of two hexadecimal switches. Adjusting this voltage directly affects the HVPS voltage and, hence, the signal from the PMT. Secondly, the gain of the amplified signal can further be adjusted through a potentiometer. These adjustments should only be performed when encountering problems with the software calibration that cannot be rectified otherwise. Refer to Section 12.7.2.8 for this hardware calibration.
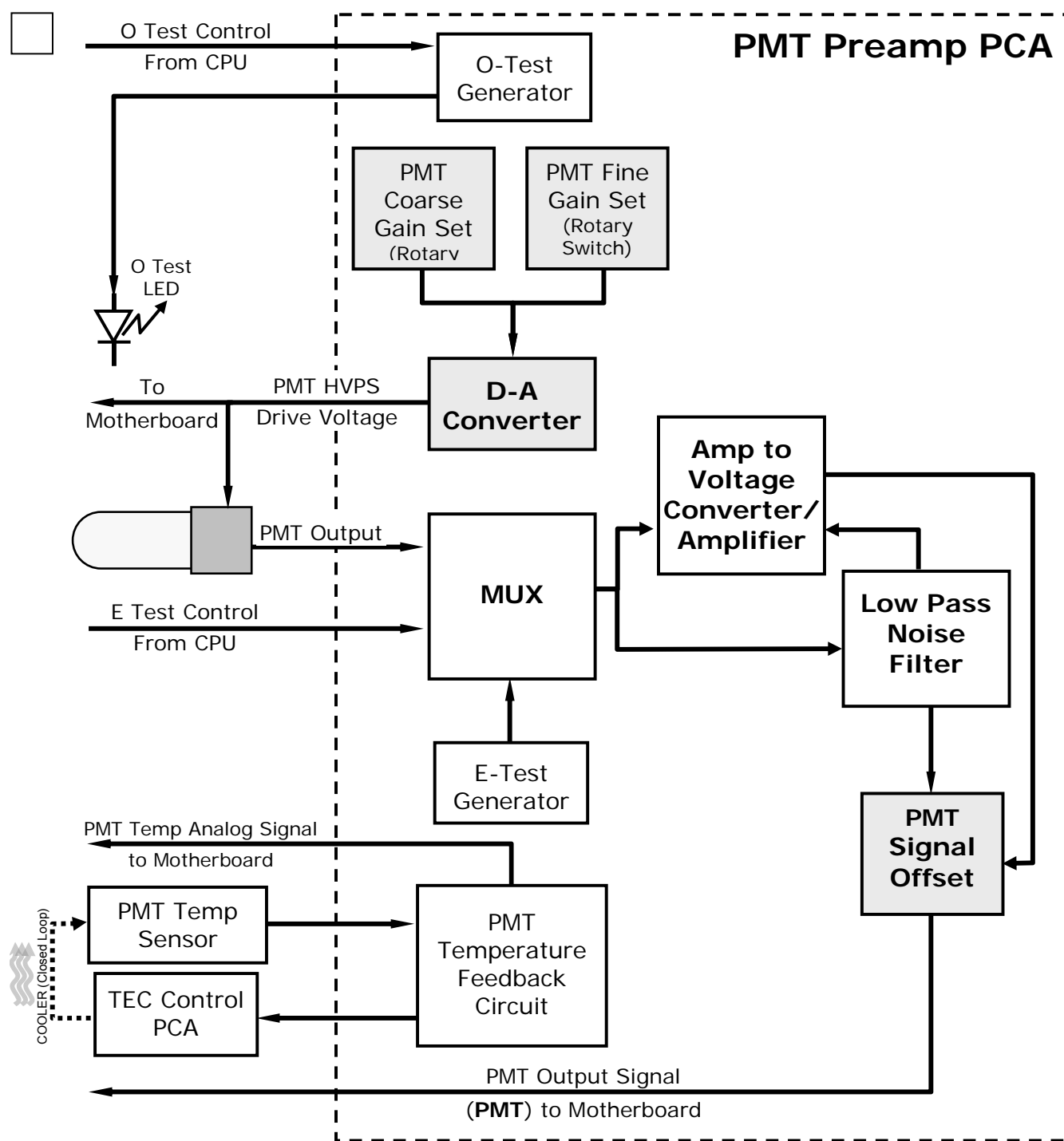
Figure 13-20:   PMT Preamp Block Diagram

The PMT temperature control loop maintains the PMT temperature around 7° C and can be viewed as test function **PMT TEMP** on the front panel (refer to Section 4.1.1).

The electrical test (**ETEST**) circuit generates a constant, electronic signal intended to simulate the output of the PMT (after conversion from current to voltage). By bypassing the detector's actual signal, it is possible to test most of the signal handling and

conditioning circuitry on the PMT preamplifier board. Refer to Section 5.9.5 for instructions on performing this test.

The optical test (**OTEST**) feature causes an LED inside the PMT cold block to create a light signal that can be measured with the PMT. If zero air is supplied to the analyzer, the entire measurement capability of the sensor module can be tested including the PMT and the current to voltage conversion circuit on the PMT preamplifier board. Refer to Section 5.9.4 for instructions on performing this test.

13.5.6. PNEUMATIC SENSOR BOARD

The flow and pressure sensors of the T100 are located on a printed circuit assembly just behind the PMT sensor. Refer to Section 12.6.15 on how to test this assembly. The signals of this board are supplied to the motherboard for further signal processing. All sensors are linearized in the firmware and can be span calibrated from the front panel. Refer to Section 5.4.3.2 for instructions on performing this test.

13.5.7. RELAY BOARD

The relay board is the central switching unit of the analyzer. It contains power relays, status LEDs for all heated zones and valves, as well as valve drivers, thermocouple amplifiers, power distribution connectors and the two switching power supplies of the analyzer. The relay board communicates with the motherboard over the I^{2}C bus and is the main board for trouble-shooting power problems of any kind.

13.5.7.1. HEATER CONTROL

The T100 uses a variety of heaters for its individual components. All heaters are AC powered and can be configured for 100/120 VAC or 220/230VAC at 50-60 Hz.

The two sample chamber heaters are electronically connected in parallel for analyzers at 100/120 VAC line power and in series for units configured for 220/230 VAC. One configuration plug on the relay board determines the power configuration for the entire analyzer.

On units with IZS options installed, an additional set of AC heaters is attached to the IZS permeation tube. Some special T100 models may have other, non-standard heating zones installed, such as a dilution manifold.

13.5.7.2. VALVE CONTROL

The relay board also hosts two valve driver chips, each of which can drive up four valves. In its basic configuration the T100 requires no valve control to operate. However, on units with either the zero/span valve or the IZS option installed, the valve control is used. Manifold valves, which may also be present in certain special versions of the analyzer, would also use valve control.

13.5.7.3. **STATUS LEDS & WATCH DOG CIRCUITRY**
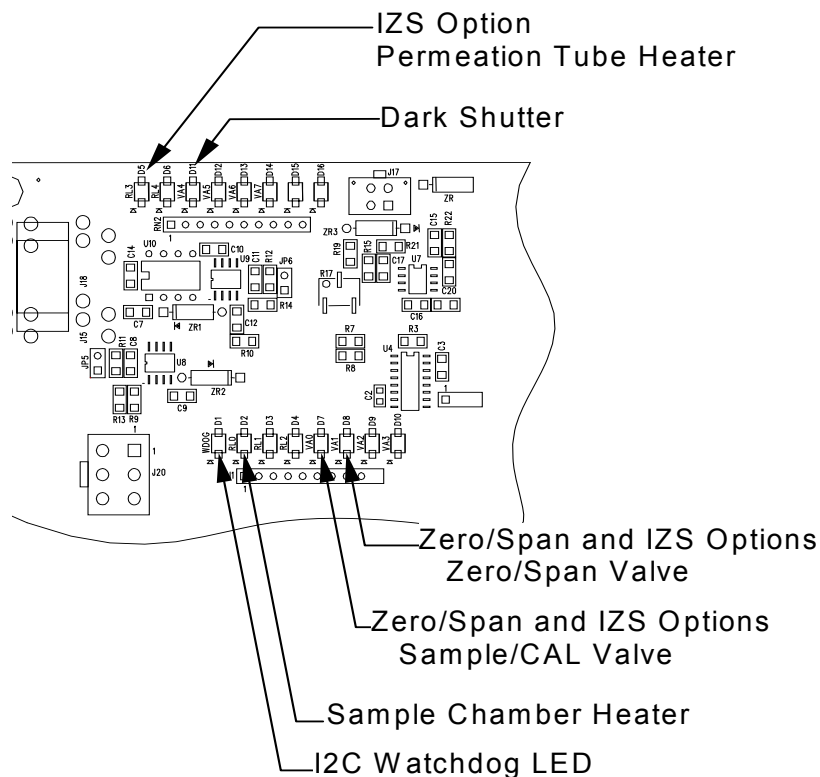
Figure 13-21:   **Relay Board Status LED Locations**

Thirteen LEDs are located on the analyzer's relay board to indicate the status of the analyzer's heating zones and valves as well as a general operating watchdog indicator. Table 13-1 shows the state of these LEDs and their respective functionality.

Table 13-1:   **Relay Board Status LED's**

LED	COLOR	FUNCTION	STATUS WHEN LIT	STATUS WHEN UNLIT
D1	RED	Watchdog circuit	Cycles On/Off every 3 seconds under control of the CPU.	
D2	YELLOW	Sample chamber (RCELL) heater	HEATING	NOT HEATING
D3, D4	YELLOW	Unused	N/A	N/A
D5	YELLOW	IZS heater (option)	HEATING	NOT HEATING
D6	YELLOW	Unused	N/A	N/A
D7	GREEN	Zero / Span Valve	Valve open to Span Gas path	Valve open to Zero Gas (normal state)
D8	GREEN	Sample / Cal Valve	Valve open to calibration gas path	Valve open to sample gas inlet on rear panel (normal state)
D9, D10	GREEN	Unused	N/A	N/A
D11	GREEN	UV Lamp Shutter	Shutter open	Shutter closed
D12-14	GREEN	Unused	N/A	N/A

As a safety measure, special circuitry on the relay board watches the status of LED D1. Should this LED ever stay **ON** or **OFF** for 30 seconds, indicating that the CPU or I^2C bus has stopped functioning, the Watchdog Circuit will automatically shut of all valves as well as turn off the UV Source(s) and all heaters. The Sample pump will still be running.

13.5.8. MOTHERBOARD

This printed circuit assembly provides a multitude of functions including A/D conversion, digital input/output, PC-104 to I^2C translation, temperature sensor signal processing and is a pass through for the RS-232 and RS-485 signals.

13.5.8.1. A TO D CONVERSION

Analog signals, such as the voltages received from the analyzer's various sensors, are converted into digital signals that the CPU can understand and manipulate by the Analog to Digital converter (A/D).Under the control of the CPU, this functional block selects a particular signal input and then coverts the selected voltage into a digital word.

The A/D consists of a Voltage-to-Frequency (V-F) converter, a Programmable Logic Device (PLD), three multiplexers, several amplifiers and some other associated devices. The V-F converter produces a frequency proportional to its input voltage. The PLD counts the output of the V-F during a specified time period, and sends the result of that count, in the form of a binary number, to the CPU.

The A/D can be configured for several different input modes and ranges but it is used in uni-polar mode with a +5V full scale. The converter includes a 1% over and under-range. This allows signals from -0.05V to +5.05V to be fully converted.

For calibration purposes, two reference voltages are supplied to the A/D converter: Reference ground and +4.096 VDC. During calibration, the device measures these two voltages, outputs their digital equivalent to the CPU. The CPU uses these values to compute the converter's offset and slope and uses these factors for subsequent conversions. Refer to Section 5.9.3.6 for instructions on performing this calibration.

13.5.8.2. SENSOR INPUTS

The key analog sensor signals are coupled to the A/D through the master multiplexer from two connectors on the motherboard. 100K terminating resistors on each of the inputs prevent cross talk from appearing on the sensor signals.

PMT DETECTOR OUTPUT: This signal, output by the PMT preamp PCA, is used in the computation of the SO_2, CO_2 and O_2 concentrations displayed in the front panel display screen and output through the instrument's analog outputs and **COMM** ports.

PMT HIGH VOLTAGE POWER SUPPLY LEVEL: This input is based on the drive voltage output by the PMT pram board to the PMT's high voltage power supply (HVPS). It is digitized and sent to the CPU where it is used to calculate the voltage setting of the HVPS and stored in the instruments memory as the test function **HVPS. HVPS** is viewable as a test function (refer to Section 4.1.1) through the analyzer's front panel.

PMT TEMPERATURE: This signal is the output of the thermistor attached to the PMT cold block amplified by the PMT temperature feedback circuit on the PMT preamp board. It is digitized and sent to the CPU where it is used to calculate the current temperature of the PMT.

This measurement is stored in the analyzer. Memory as the test function **PMT TEMP** and is viewable as a test function (refer to Section 4.1.1) through the analyzer's front panel.

SAMPLE GAS PRESSURE SENSOR: This sensor measures the gas pressure at the exit of the sample chamber.

SAMPLE FLOW SENSOR: This sensor measure the flow rate of the sample gas as it exits the sample chamber.

13.5.8.3. THERMISTOR INTERFACE

This circuit provides excitation, termination and signal selection for several negative-coefficient, thermistor temperature sensors located inside the analyzer. They are as follows:

SAMPLE CHAMBER TEMPERATURE SENSOR: The source of this signal is a thermistor imbedded in the of the sample chamber block. It measures the temperature of the sample gas in the chamber. The data are used by the CPU to control sample chamber the heating circuit and as part of the SO_2, calculations when the instrument's Temperature/Pressure Compensation feature is enabled.

This measurement is stored in the analyzer. Memory as the Test Function **RCEL TEMP** and is viewable as a test function (refer to Section 4.1.1) in the analyzer's front panel display.

IZS OPTION PERMEATION TUBE TEMPERATURE SENSOR: This thermistor, attached to the permeation tube in the IZS option, reports the current temperature of that tube to the CPU as part of control loop that keeps the tube at a constant temperature.

BOX TEMPERATURE SENSOR: A thermistor is attached to the motherboard. It measures the analyzer's internal temperature. This information is stored by the CPU and can be viewed by the user for troubleshooting purposes through the front panel display. This measurement is stored in the analyzer's memory as the test function **BOX TEMP** and is viewable as a test function (refer to Section 4.1.1) in the analyzer's front panel display.

13.5.9. ANALOG OUTPUTS

The analyzer comes equipped with four Analog Outputs: **A1**, **A2**, **A3** and a fourth that is a spare.

A1 and A2 Outputs: The first two, **A1** and **A2** are normally set up to operate in parallel so that the same data can be sent to two different recording devices. While the names imply that one should be used for sending data to a chart recorder and the other for interfacing with a data logger, either can be used for both applications.

Both of these channels output a signal that is proportional to the SO_2 concentration of the sample gas. The **A1** and **A2** outputs can be slaved together or set up to operated independently. A variety of scaling factors are available; refer to Section 5.4 for information on setting the range type and Section 5.9.3 for adjusting the electronic scaling factors of these output channels

Test Output: The third analog output, labeled **A3** is special. It can be set by the user (refer to Section 5.9.9) to carry the signal level of any one of the parameters accessible through the **TEST** menu of the unit's software.

In its standard configuration, the analyzer comes with all four of these channels set up to output a DC voltage. However, 4-20mA current loop drivers can be purchased for the first two of these outputs (**A1** and **A2**). Refer to Sections 1.4 (Option 41), 3.3.1.3 and 5.9.3.5.

Output Loop-back: All three of the functioning analog outputs are connected back to the A/D converter through a Loop-back circuit. This permits the voltage outputs to be calibrated by the CPU without need for any additional tools or fixtures (refer to Section 5.9.3.2).

13.5.10. EXTERNAL DIGITAL I/O

This External Digital I/O performs two functions.

STATUS OUTPUTS: Logic-Level voltages are output through an optically isolated 8-pin connector located on the rear panel of the analyzer. These outputs convey good/bad and on/off information about certain analyzer conditions. They can be used to interface with certain types of programmable devices (refer to Section 8.1.1).

CONTROL INPUTS: By applying +5VDC power supplied from an external source such as a PLC or Data logger (refer to Section 8.1.2), Zero and Span calibrations can be initiated by contact closures on the rear panel.

13.5.11. I^{2}C DATA BUS

I^{2}C is a two-wire, clocked, bi-directional, digital serial I/O bus that is used widely in commercial and consumer electronic systems. A transceiver on the Motherboard converts data and control signals from the PC-104 bus to I^{2}C. The data is then fed to the relay board and optional analog input circuitry.

13.5.12. POWER UP CIRCUIT

This circuit monitors the +5V power supply during start-up and sets the Analog outputs, External Digital I/O ports, and I^{2}C circuitry to specific values until the CPU boots and the instrument software can establish control.

13.5.13. POWER SUPPLY/ CIRCUIT BREAKER

The analyzer operates on 100 VAC, 115 VAC or 230 VAC power at either 50Hz or 60Hz. Individual units are set up at the factory to accept any combination of these five attributes. As illustrated in Figure 13-22 below, power enters the analyzer through a standard IEC 320 power receptacle located on the rear panel of the instrument. From there it is routed through the ON/OFF switch located in the lower right corner of the front panel.

AC line power is stepped down and converted to DC power by two DC power supplies. One supplies +12 VDC, for various valves and valve options, while a second supply provides +5 VDC and ±15 VDC for logic and analog circuitry as well as the TEC cooler. All AC and DC Voltages are distributed through the relay board.

A 6.75 ampere circuit breaker is built into the ON/OFF switch. In case of a wiring fault or incorrect supply power, the circuit breaker will automatically turn off the analyzer.

WARNING

Should the power circuit breaker trip, correct the condition causing this situation before turning the analyzer back on.
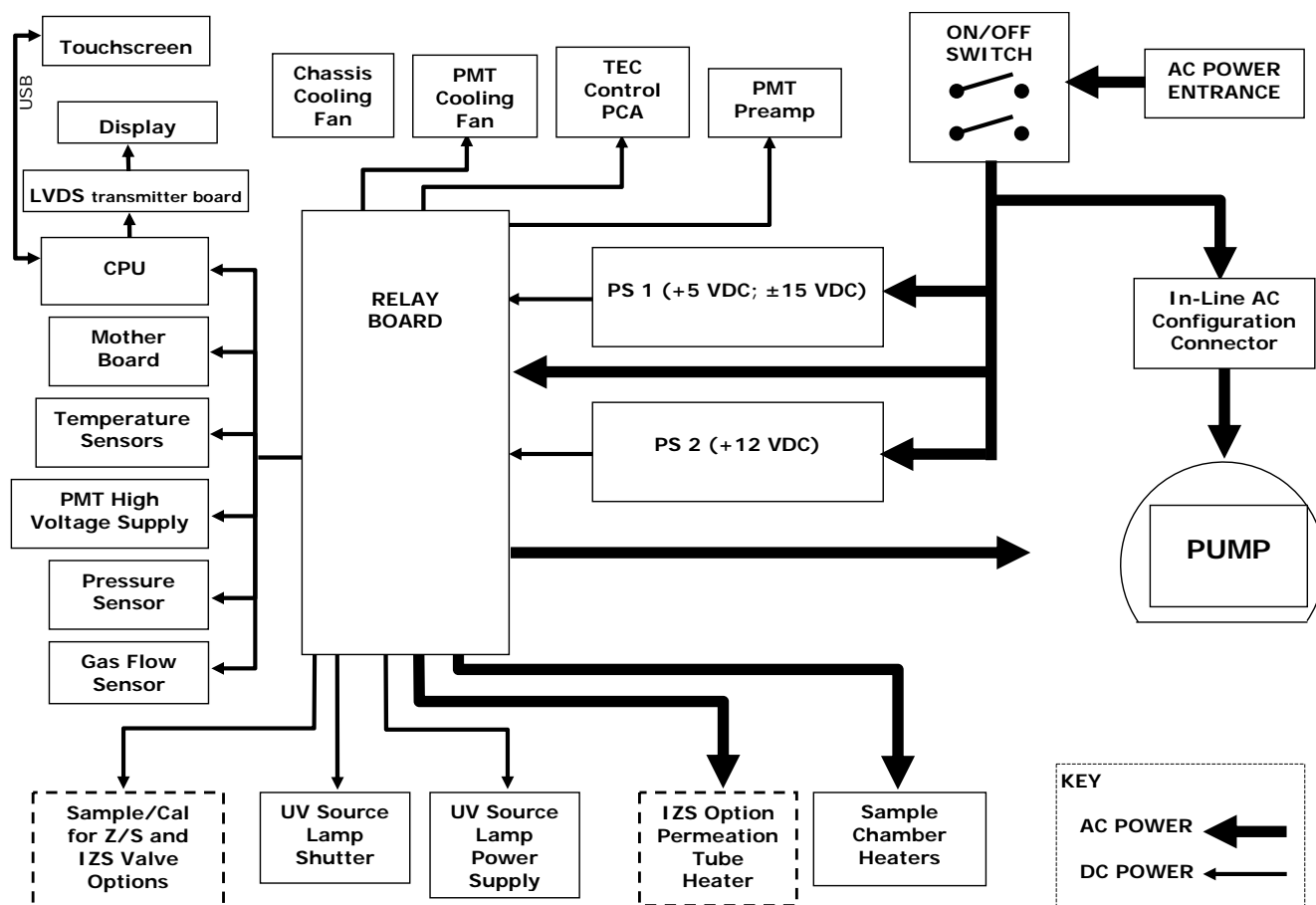
Figure 13-22:   Power Distribution Block Diagram

13.6. FRONT PANEL/DISPLAY INTERFACE

Users can input data and receive information directly through the front panel touch-screen display. The LCD display is controlled directly by the CPU board. The touchscreen is interfaced to the CPU by means of a touchscreen controller that connects to the CPU via the internal USB bus and emulates a computer mouse.
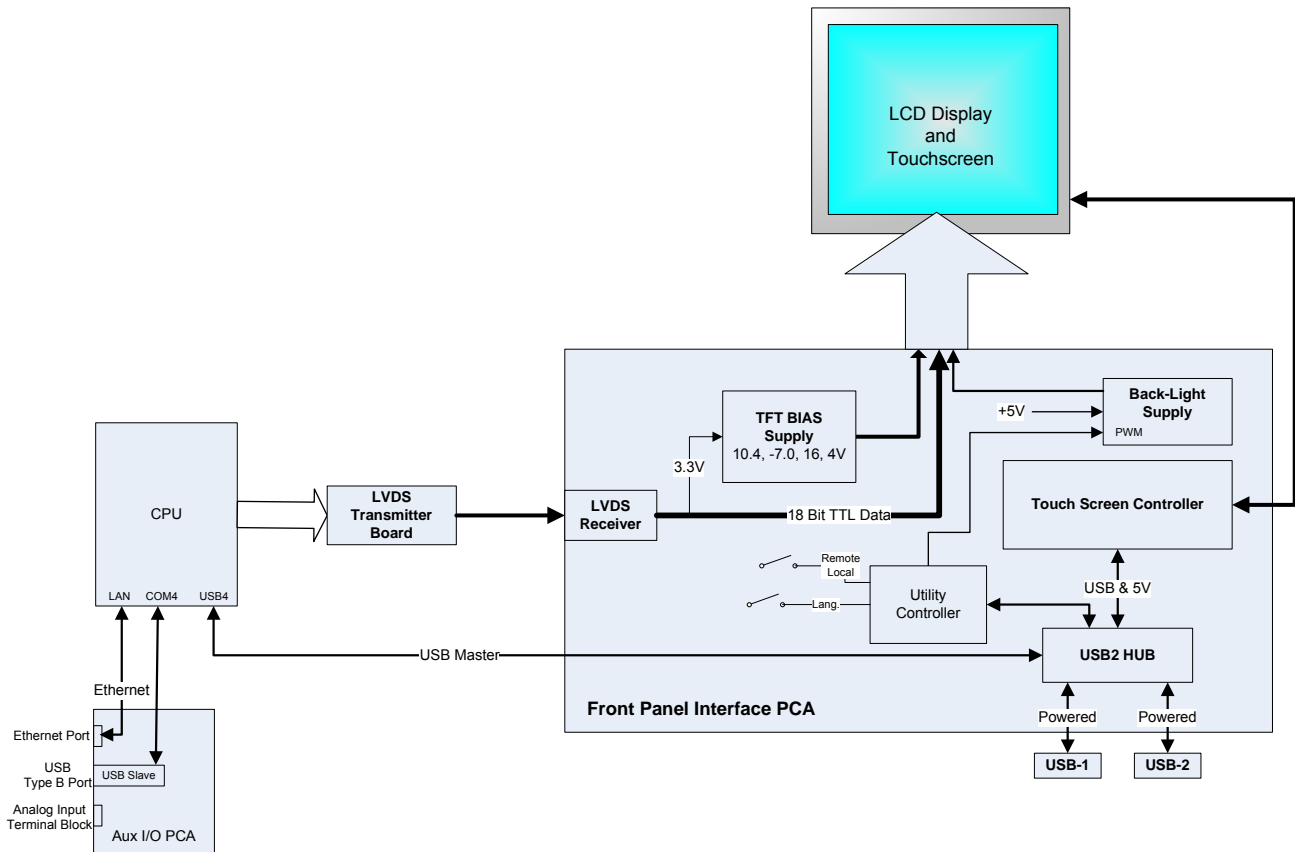
Figure 13-23:   Front Panel and Display Interface Block Diagram

13.6.1. LVDS TRANSMITTER BOARD

The LVDS (low voltage differential signaling) transmitter board converts the parallel display bus to a serialized, low voltage, differential signal bus in order to transmit the video signal to the LCD interface PCA.

13.6.2. FRONT PANEL INTERFACE PCA

The front panel interface PCA controls the various functions of the display and touchscreen. For driving the display it provides connection between the CPU video controller and the LCD display module. This PCA also contains:

- power supply circuitry for the LCD display module

- a USB hub that is used for communications with the touchscreen controller and the two front panel USB device ports

- the circuitry for powering the display backlight

13.7. SOFTWARE OPERATION

The instrument's core module is a high performance, X86-based microcomputer running Windows CE. Inside Windows CE, special software developed by Teledyne API interprets user commands from the various interfaces, performs procedures and tasks, stores data in the CPU's various memory devices and calculates the concentration of the gas being sampled.
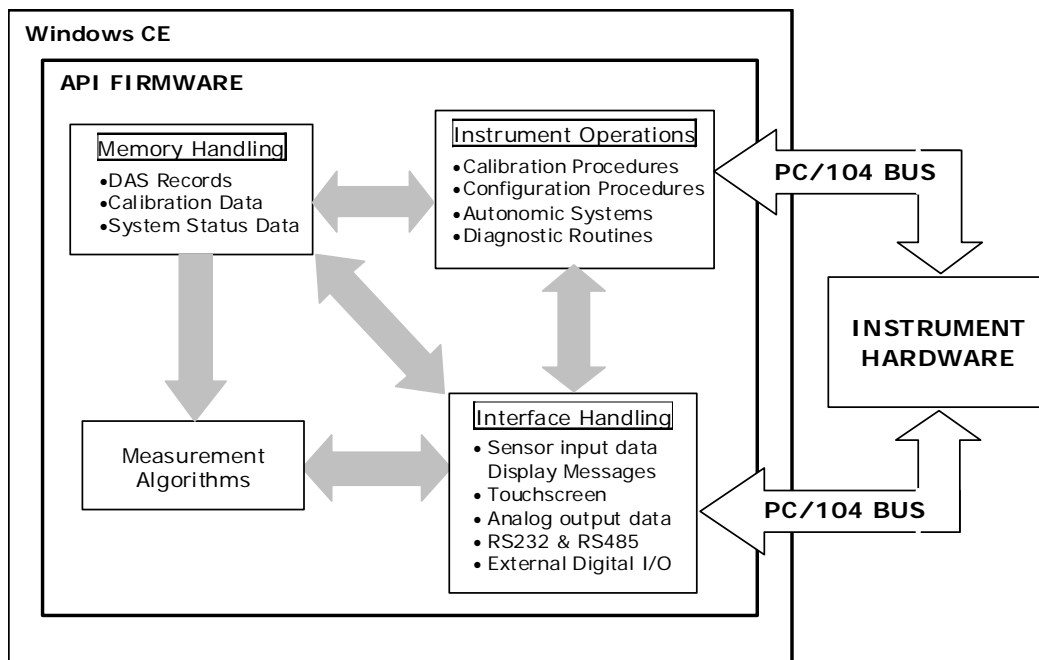
Figure 13-24:   Basic Software Operation

13.7.1. ADAPTIVE FILTER

The T100 SO$_2$ analyzer software processes sample gas measurement and reference data through an adaptive filter built into the software. Unlike other analyzers that average the sensor output signal over a fixed time period, the T100 calculates averages over a set number of samples where each sample is 1 second. During operation, the software automatically switches between two filters of different lengths based on the conditions at hand.

During conditions of constant or nearly constant concentration the software computes an average of the last 240 samples or 240 seconds. This provides the calculation portion of the software with smooth, stable readings. If a rapid change in concentration is detected, the adaptive filter switches modes and only averages the last 20 samples or 20 seconds. This allows the analyzer to respond to the rapidly changing concentration more quickly. Once triggered, the short filter remains engaged for a fixed time period to prevent chattering.

Two conditions must be simultaneously met to switch to the short filter. First the instantaneous concentration must exceed the average in the long filter by a fixed

amount. Second, the instantaneous concentration must exceed the average in the long filter by a portion, or percentage, of the average in the long filter.

If necessary, these filter lengths of these two modes may be changed to any value between 1 and 1000 samples. Long sample lengths provide better signal to noise rejection, but poor response times. Conversely shorter filter lengths result in poor signal to noise rejection, but quicker response times.

13.7.2. CALIBRATION - SLOPE AND OFFSET

Calibration of the analyzer is performed exclusively in software. During instrument calibration (refer to Sections 9 and 10) the user enters expected values for zero and span through the front panel touch-screen control buttons and commands the instrument to make readings of sample gases with known concentrations of SO_2. The readings taken are adjusted, linearized, and compared to the expected values as input. With this information the software computes values for instrument both slope and offset and stores these values in memory for use in calculating the SO_2 concentration of the sample gas.

Instrument slope and offset values recorded during the last calibration can be viewed by pressing the following control buttons sequence
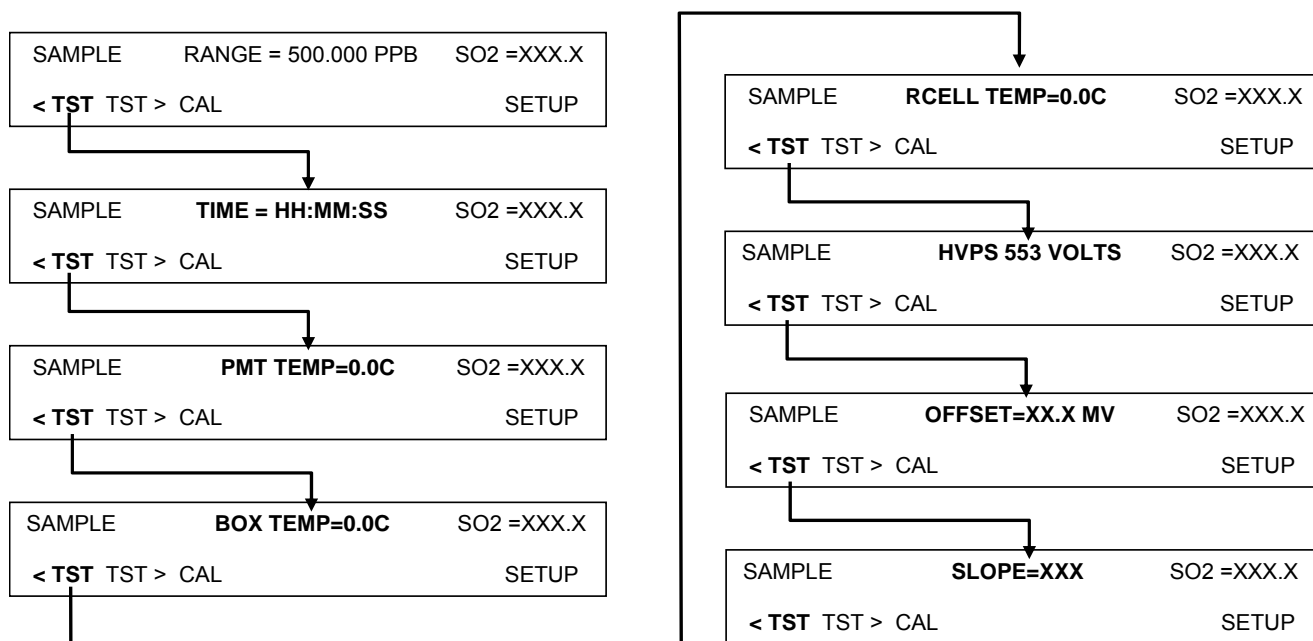
Figure 13-25: Calibration Slope and Offset

13.7.3. TEMPERATURE AND PRESSURE COMPENSATION (TPC) FEATURE

As explained in the principles of operation, changes in temperature can significantly affect the amount of fluoresced UV light generated in the instruments sample chamber. To negate this effect the T100 maintains the sample gas at a stable, raised temperature.

Pressure changes can also have a noticeable, if more subtle, effect on the SO_2 concentration calculation. To account for this, the T100 software includes a feature which allows the instrument to compensation of the SO_2 calculations based on changes in ambient pressure.

When the TPC feature is enabled, the analyzer's SO_2 concentration divided by a factor call PRESSCO which is based on the difference between the ambient pressure of the sample gas normalized to standard atmospheric pressure (Equation 13-6). As ambient pressure increases, the compensated SO_2 concentration is decreased.

$$PRESSCO = \frac{SAMPLE\_PRESSURE\ ('' HG\text{-}A) \times SAMP\_PRESS\_SLOPE}{29.92\ ('' HG\text{-}A)}$$

(Equation 13-6)

SAMPLE-PRESSURE: The ambient pressure of the sample gas as measured by the instrument's sample pressure sensor in "Hg-A.

SAMP_PRESS_SLOPE: Sample pressure slope correction factor. The default setting for Section 6.8 describes the method for enabling/disabling the TPC feature.

13.7.4. INTERNAL DATA ACQUISITION SYSTEM (DAS)

The DAS is designed to implement predictive diagnostics that stores trending data for users to anticipate when an instrument will require service. Large amounts of data can be stored in non-volatile memory and retrieved in plain text format for further processing with common data analysis programs. The DAS has a consistent user interface in all Teledyne API instruments. New data parameters and triggering events can be added to the instrument as needed.

Depending on the sampling frequency and the number of data parameters the DAS can store several months of data, which are retained even when the instrument is powered off or a new firmware is installed. The DAS permits users to access the data through the instrument's front panel or the remote interface. The latter can automatically download stored data for further processing. For information on using the DAS, refer to Section 0.

14. A PRIMER ON ELECTRO-STATIC DISCHARGE

Teledyne API considers the prevention of damage caused by the discharge of static electricity to be extremely important part of making sure that your analyzer continues to provide reliable service for a long time. This section describes how static electricity occurs, why it is so dangerous to electronic components and assemblies as well as how to prevent that damage from occurring.

ATTENTION

COULD DAMAGE INSTRUMENT AND VOID WARRANTY

Read this chapter completely and follow instructions carefully.

14.1. HOW STATIC CHARGES ARE CREATED

Modern electronic devices such as the types used in the various electronic assemblies of your analyzer, are very small, require very little power and operate very quickly. Unfortunately, the same characteristics that allow them to do these things also make them very susceptible to damage from the discharge of static electricity. Controlling electrostatic discharge begins with understanding how electro-static charges occur in the first place.

Static electricity is the result of something called triboelectric charging which happens whenever the atoms of the surface layers of two materials rub against each other. As the atoms of the two surfaces move together and separate, some electrons from one surface are retained by the other.
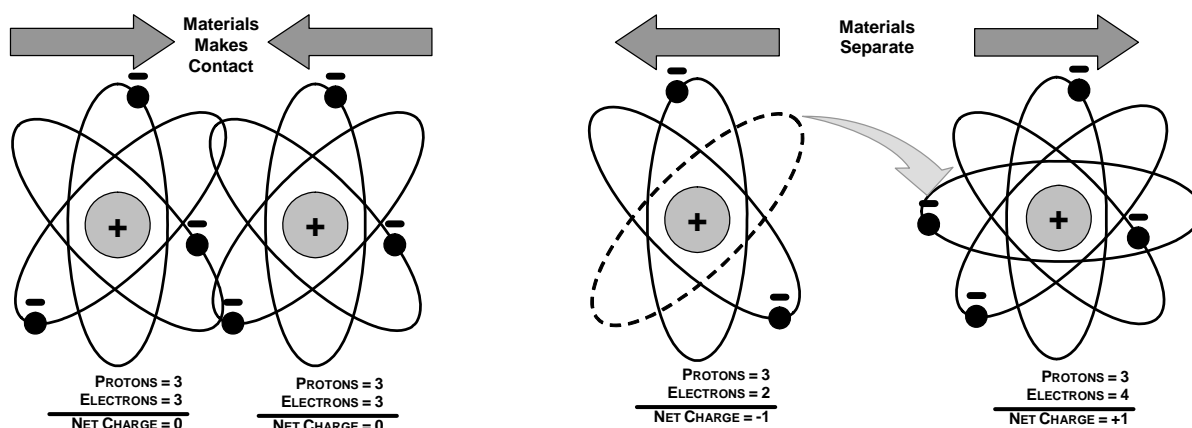
Figure 14-1:   Triboelectric Charging

If one of the surfaces is a poor conductor or even a good conductor that is not grounded, the resulting positive or negative charge cannot bleed off and becomes trapped in place, or static. The most common example of triboelectric charging happens when someone wearing leather or rubber soled shoes walks across a nylon carpet or linoleum tiled floor. With each step, electrons change places and the resulting electro-static charge builds up, quickly reaching significant levels. Pushing an epoxy printed circuit board across a workbench, using a plastic handled screwdriver or even the constant jostling of Styrofoam^{TM} pellets during shipment can also build hefty static charges

Table 14-1: Static Generation Voltages for Typical Activities

MEANS OF GENERATION	65-90% RH	10-25% RH
Walking across nylon carpet	1,500V	35,000V
Walking across vinyl tile	250V	12,000V
Worker at bench	100V	6,000V
Poly bag picked up from bench	1,200V	20,000V
Moving around in a chair padded with urethane foam	1,500V	18,000V

14.2. HOW ELECTRO-STATIC CHARGES CAUSE DAMAGE

Damage to components occurs when these static charges come into contact with an electronic device. Current flows as the charge moves along the conductive circuitry of the device and the typically very high voltage levels of the charge overheat the delicate traces of the integrated circuits, melting them or even vaporizing parts of them. When examined by microscope the damage caused by electro-static discharge looks a lot like tiny bomb craters littered across the landscape of the component's circuitry.

A quick comparison of the values in Table 14-1 with the those shown in the Table 14-2, listing device susceptibility levels, shows why *Semiconductor Reliability News* estimates that approximately 60% of device failures are the result of damage due to electro-static discharge.

Table 14-2: Sensitivity of Electronic Devices to Damage by ESD

DEVICE	DAMAGE SUSCEPTIBILITY VOLTAGE RANGE	
	DAMAGE BEGINS OCCURRING AT	CATASTROPHIC DAMAGE AT
MOSFET	10	100
VMOS	30	1800
NMOS	60	100
GaAsFET	60	2000
EPROM	100	100
JFET	140	7000
SAW	150	500
Op-AMP	190	2500
CMOS	200	3000
Schottky Diodes	300	2500
Film Resistors	300	3000
This Film Resistors	300	7000
ECL	500	500
SCR	500	1000
Schottky TTL	500	2500

Potentially damaging electro-static discharges can occur:

- Any time a charged surface (including the human body) discharges to a device. Even simple contact of a finger to the leads of a sensitive device or assembly can allow enough discharge to cause damage. A similar discharge can occur from a charged conductive object, such as a metallic tool or fixture.

- When static charges accumulated on a sensitive device discharges from the device to another surface such as packaging materials, work surfaces, machine surfaces or other device. In some cases, charged device discharges can be the most destructive.

  A typical example of this is the simple act of installing an electronic assembly into the connector or wiring harness of the equipment in which it is to function. If the assembly is carrying a static charge, as it is connected to ground a discharge will occur.

- Whenever a sensitive device is moved into the field of an existing electro-static field, a charge may be induced on the device in effect discharging the field onto the device. If the device is then momentarily grounded while within the electrostatic field or removed from the region of the electrostatic field and grounded somewhere else, a second discharge will occur as the charge is transferred from the device to ground.

14.3. COMMON MYTHS ABOUT ESD DAMAGE

- **I didn't feel a shock so there was no electro-static discharge**: The human nervous system isn't able to feel a static discharge of less than 3500 volts. Most devices are damaged by discharge levels much lower than that.

- **I didn't touch it so there was no electro-static discharge**: Electro-static charges are fields whose lines of force can extend several inches or sometimes even feet away from the surface bearing the charge.

- **It still works so there was no damage**: Sometimes the damaged caused by electro-static discharge can completely sever a circuit trace causing the device to fail immediately. More likely, the trace will be only partially occluded by the damage causing degraded performance of the device or worse, weakening the trace. This weakened circuit may seem to function fine for a short time, but even the very low voltage and current levels of the device's normal operating levels will eat away at the defect over time causing the device to fail well before its designed lifetime is reached.

  These latent failures are often the most costly since the failure of the equipment in which the damaged device is installed causes down time, lost data, lost productivity, as well as possible failure and damage to other pieces of equipment or property.

- Static Charges can't build up on a conductive surface: There are two errors in this statement.

  Conductive devices can build static charges if they are not grounded. The charge will be equalized across the entire device, but without access to earth ground, they are still trapped and can still build to high enough levels to cause damage when they are discharged.

  A charge can be induced onto the conductive surface and/or discharge triggered in the presence of a charged field such as a large static charge clinging to the surface of a nylon jacket of someone walking up to a workbench.

- **As long as my analyzer is properly installed, it is safe from damage caused by static discharges**: It is true that when properly installed the chassis ground of your analyzer is tied to earth ground and its electronic components are prevented from building static electric charges themselves. This does not prevent discharges from static fields built up on other things, like you and your clothing, from discharging through the instrument and damaging it.

14.4. BASIC PRINCIPLES OF STATIC CONTROL

It is impossible to stop the creation of instantaneous static electric charges. It is not, however difficult to prevent those charges from building to dangerous levels or prevent damage due to electro-static discharge from occurring.

14.4.1. GENERAL RULES

Only handle or work on all electronic assemblies at a properly set up ESD station. Setting up an ESD safe workstation need not be complicated. A protective mat properly tied to ground and a wrist strap are all that is needed to create a basic anti-ESD workstation (refer to figure 12-2).
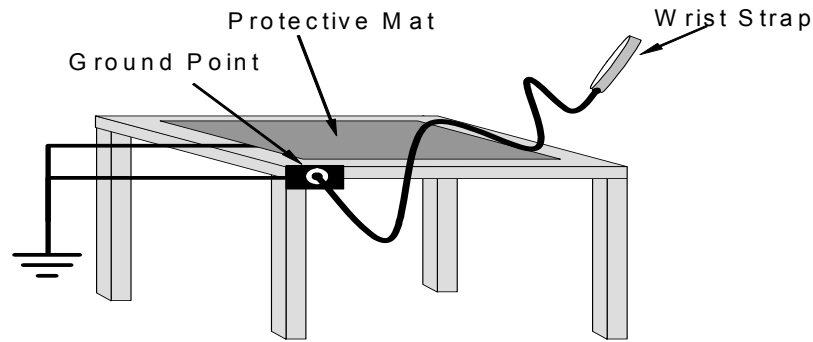
Figure 14-2:   Basic anti-ESD Work Station

For technicians that work in the field, special lightweight and portable anti-ESD kits are available from most suppliers of ESD protection gear. These include everything needed to create a temporary anti-ESD work area anywhere.

- **Always wear an Anti-ESD wrist strap when working on the electronic assemblies of your analyzer**. An anti-ESD wrist strap keeps the person wearing it at or near the same potential as other grounded objects in the work area and allows static charges to dissipate before they can build to dangerous levels. Anti-ESD wrist straps terminated with alligator clips are available for use in work areas where there is no available grounded plug.

  Also, anti-ESD wrist straps include a current limiting resistor (usually around one meg-ohm) that protects you should you accidentally short yourself to the instrument's power supply.

- **Simply touching a grounded piece of metal is insufficient**. While this may temporarily bleed off static charges present at the time, once you stop touching the grounded metal new static charges will immediately begin to re-build. In some conditions, a charge large enough to damage a component can rebuild in just a few seconds.

- **Always store sensitive components and assemblies in anti-ESD storage bags or bins:** Even when you are not working on them, store all devices and assemblies in a closed anti-Static bag or bin. This will prevent induced charges from building up on the device or assembly and nearby static fields from discharging through it.

- **Use metallic anti-ESD bags for storing and shipping ESD sensitive components and assemblies rather than pink-poly bags.** The famous, "pink-poly" bags are made of a plastic that is impregnated with a liquid (similar to liquid laundry detergent) which very slowly sweats onto the surface of the plastic creating a slightly conductive layer over the surface of the bag.

  While this layer may equalizes any charges that occur across the whole bag, it does not prevent the build up of static charges. If laying on a conductive, grounded surface, these bags will allow charges to bleed away but the very charges that build up on the surface of the bag itself can be transferred through the bag by induction onto the circuits of your ESD sensitive device. Also, the

liquid impregnating the plastic is eventually used up after which the bag is as useless for preventing damage from ESD as any ordinary plastic bag.

Anti-Static bags made of plastic impregnated with metal (usually silvery in color) provide all of the charge equalizing abilities of the pink-poly bags but also, when properly sealed, create a Faraday cage that completely isolates the contents from discharges and the inductive transfer of static charges.

Storage bins made of plastic impregnated with carbon (usually black in color) are also excellent at dissipating static charges and isolating their contents from field effects and discharges.

- **Never use ordinary plastic adhesive tape near an ESD sensitive device or close to an anti-ESD bag.** The act of pulling a piece of standard plastic adhesive tape, such as Scotch® tape, from its roll will generate a static charge of several thousand or even tens of thousands of volts on the tape itself and an associated field effect that can discharge through or be induced upon items up to a foot away.

14.5. BASIC ANTI-ESD PROCEDURES FOR ANALYZER REPAIR AND MAINTENANCE

This section provides guidance for working properly at either the instrument rack or the bench, including transferring components back and forth between the two. Also presented are instructions for properly opening shipments and unpacking, and for packing and sealing components for shipping

14.5.1. WORKING AT THE INSTRUMENT RACK

When working on the analyzer while it is in the instrument rack and plugged into a properly grounded power supply.

1. Attach your anti-ESD wrist strap to ground before doing anything else.

- Use a wrist strap terminated with an alligator clip and attach it to a bare metal portion of the instrument chassis. This will safely connect you to the same ground level to which the instrument and all of its components are connected.

2. Pause for a second or two to allow any static charges to bleed away.

3. Open the casing of the analyzer and begin work. Up to this point, the closed metal casing of your analyzer has isolated the components and assemblies inside from any conducted or induced static charges.

4. If you must remove a component from the instrument, do not lay it down on a non-ESD preventative surface where static charges may lie in wait.

5. Only disconnect your wrist strap after you have finished work and closed the case of the analyzer.

14.5.2. WORKING AT AN ANTI-ESD WORK BENCH

When working on an instrument of an electronic assembly while it is resting on an anti-ESD work bench:

1. Plug your anti-ESD wrist strap into the grounded receptacle of the work station before touching any items on the work station and while standing at least a foot or so away. This will allow any charges you are carrying to bleed away through the ground connection of the workstation and prevent discharges due to field effects and induction from occurring.

2. Pause for a second or two to allow any static charges to bleed away.

3. Only after you have plugged your wrist strap into the workstation and allowed static charges to bleed away, open any anti-ESD storage bins or bags containing sensitive devices or assemblies, as follows:

- Lay the bag or bin on the workbench surface.

- Before opening the container, wait several seconds for any static charges on the outside surface of the container to be bled away by the workstation's grounded protective mat.

4. Do not pick up tools that may be carrying static charges while also touching or holding an ESD Sensitive Device.

- Only lay tools or ESD-sensitive devices and assemblies on the conductive surface of your workstation. Never lay them down on any non-ESD preventative surface.

5. Before unplugging your wrist strap, place any static sensitive devices or assemblies in anti-static storage bags or bins and close the bag or bin.

6. Disconnecting your wrist strap is always the last action taken before leaving the workbench.

14.5.3. TRANSFERRING COMPONENTS BETWEEN RACK AND BENCH

When transferring a sensitive device from an installed Teledyne API analyzer to an Anti-ESD workbench or back:

1. Follow the instructions listed above for working at the instrument rack and workstation.

2. Never carry the component or assembly without placing it in an anti-ESD bag or bin.

3. Before using the bag or container allow any surface charges on it to dissipate:

- If you are at the instrument rack, hold the bag in one hand while your wrist strap is connected to a ground point.

- If you are at an anti-ESD workbench, lay the container down on the conductive work surface while your wrist strap is connected to a ground point.

- In either case wait several seconds.

4. Place the item in the container.

5. Seal the container. If using a bag, fold the end over and fasten it with anti-ESD tape.

- Folding the open end over isolates the component(s) inside from the effects of static fields.

- Leaving the bag open or simply stapling it shut without folding it closed prevents the bag from forming a complete protective envelope around the device.

6. Once you have arrived at your destination, allow any surface charges that may have built up on the bag or bin during travel to dissipate:

- Connect your wrist strap to ground.

- If you are at the instrument rack, hold the bag in one hand while your wrist strap is connected to a ground point.

- If you are at a anti-ESD work bench, lay the container down on the conductive work surface

- In either case wait several seconds

7. Open the container.

14.5.4. OPENING SHIPMENTS FROM TELEDYNE

Packing materials such as bubble pack and Styrofoam pellets are extremely efficient generators of static electric charges. To prevent damage from ESD, Teledyne API ships all electronic components and assemblies in properly sealed anti-ESD containers.

Static charges will build up on the outer surface of the anti-ESD container during shipping as the packing materials vibrate and rub against each other. To prevent these static charges from damaging the components or assemblies being shipped ensure that you always unpack shipments from Teledyne API by:

1. Opening the outer shipping box away from the anti-ESD work area.

2. Carry the still sealed ant-ESD bag, tube or bin to the anti-ESD work area.

3. Follow steps 6 and 7 of Section 14.5.3 above when opening the anti-ESD container at the work station.

4. Reserve the anti-ESD container or bag to use when packing electronic components or assemblies to be returned to Teledyne API.

14.5.5. PACKING COMPONENTS FOR RETURN TO TELEDYNE API

> **ATTENTION – COULD DAMAGE INSTRUMENT AND VOID WARRANTY**
> - **Always pack electronic components and assemblies to be sent to Teledyne API's Technical Support in anti-ESD bins, tubes or bags. DO NOT use pink-poly bags.**
> - **NEVER allow any standard plastic packaging materials to touch the electronic component/assembly directly.**
> - **This includes, but is not limited to, plastic bubble-pack, Styrofoam peanuts, open cell foam, closed cell foam, and adhesive tape.**
> - **DO NOT use standard adhesive tape as a sealer. Use ONLY anti-ESD tape.**

1. Open the outer shipping box away from the anti-ESD work area.

2. Carry the still sealed anti-ESD bag, tube or bin to the anti-ESD work area.

3. Follow steps 6 and 7 of Section 14.5.3 above when opening the anti-ESD container at the work station.

4. Reserve the anti-ESD container or bag to use when packing electronic components or assemblies to be returned to Teledyne API.

5. Never carry any component or assembly without placing it in an anti-ESD bag or bin.

6. Before using the bag or container, allow any surface charges on it to dissipate:

- If you are at the instrument rack, hold the bag in one hand while your wrist strap is connected to a ground point.

- If you are at an anti-ESD workbench, lay the container down on the conductive work surface.

- In either case wait several seconds.

7. Place the item in the container.
8. Seal the container. If using a bag, fold the end over and fasten it with anti-ESD tape.

- Folding the open end over isolates the component(s) inside from the effects of static fields.

- Leaving the bag open or simply stapling it shut without folding it closed prevents the bag from forming a complete protective envelope around the device.

IMPORTANT   **If you do not already have an adequate supply of anti-ESD bags or containers available, Teledyne API's Technical Support department will supply them. Follow the instructions listed above for working at the instrument rack and workstation.**

GLOSSARY

Note: Some terms in this glossary may not occur elsewhere in this manual.

Term	Description/Definition
10Base-T	an Ethernet standard that uses twisted ("T") pairs of copper wires to transmit at 10 megabits per second (Mbps)
100Base-T	same as 10BaseT except ten times faster (100 Mbps)
APICOM	name of a remote control program offered by Teledyne-API to its customers
ASSY	*Assembly*
CAS	*Code-Activated Switch*
CD	*Corona Discharge*, a frequently luminous discharge, at the surface of a conductor or between two conductors of the same transmission line, accompanied by ionization of the surrounding atmosphere and often by a power loss
CE	*Converter Efficiency*, the percentage of light energy that is actually converted into electricity
CEM	*Continuous Emission Monitoring*
Chemical formulas that may be included in this document:	
CO_2	carbon dioxide
C_3H_8	propane
CH_4	methane
H_2O	water vapor
HC	general abbreviation for hydrocarbon
HNO_3	nitric acid
H_2S	hydrogen sulfide
NO	nitric oxide
NO_2	nitrogen dioxide
NO_X	nitrogen oxides, here defined as the sum of NO and NO_2
NO_y	nitrogen oxides, often called odd nitrogen: the sum of NO_X plus other compounds such as HNO_3 (definitions vary widely and may include nitrate (NO_3), PAN, N_2O and other compounds as well)
NH_3	ammonia
O_2	molecular oxygen
O_3	ozone
SO_2	sulfur dioxide
cm^3	metric abbreviation for *cubic centimeter* (replaces the obsolete abbreviation "cc")
CPU	*Central Processing Unit*
DAC	*Digital-to-Analog Converter*
DAS	*Data Acquisition System*

Term	Description/Definition
DCE	*Data Communication Equipment*
DFU	*Dry Filter Unit*
DHCP	*Dynamic Host Configuration Protocol.* A protocol used by LAN or Internet servers to automatically set up the interface protocols between themselves and any other addressable device connected to the network
DIAG	*Diagnostics*, the diagnostic settings of the analyzer.
DOM	*Disk On Module,* a 44-pin IDE flash drive with up to 128MB storage capacity for instrument's firmware, configuration settings and data
DOS	*Disk Operating System*
DRAM	*Dynamic Random Access Memory*
DR-DOS	*Digital Research DOS*
DTE	*Data Terminal Equipment*
EEPROM	*Electrically Erasable Programmable Read-Only Memory* also referred to as a FLASH chip or drive
ESD	*Electro-Static Discharge*
ETEST	*Electrical Test*
Ethernet	a standardized (IEEE 802.3) computer networking technology for local area networks (LANs), facilitating communication and sharing resources
FEP	*Fluorinated Ethylene Propylene* polymer, one of the polymers that Du Pont markets as *Teflon*®
Flash	non-volatile, solid-state memory
FPI	*Fabry-Perot Interface*: a special light filter typically made of a transparent plate with two reflecting surfaces or two parallel, highly reflective mirrors
GFC	*Gas Filter Correlation*
I^2C bus	a clocked, bi-directional, serial bus for communication between individual analyzer components
IC	*Integrated Circuit*, a modern, semi-conductor circuit that can contain many basic components such as resistors, transistors, capacitors etc in a miniaturized package used in electronic assemblies
IP	*Internet Protocol*
IZS	*Internal Zero Span*
LAN	*Local Area Network*

Term	Description/Definition
LCD	*Liquid Crystal Display*
LED	*Light Emitting Diode*
LPM	*Liters Per Minute*
MFC	*Mass Flow Controller*
M/R	*Measure/Reference*
MOLAR MASS	the mass, expressed in grams, of 1 mole of a specific substance. Conversely, one mole is the amount of the substance needed for the molar mass to be the same number in grams as the atomic mass of that substance. EXAMPLE: The atomic weight of Carbon is 12 therefore the molar mass of Carbon is 12 grams. Conversely, one mole of carbon equals the amount of carbon atoms that weighs 12 grams. Atomic weights can be found on any Periodic Table of Elements.
NDIR	*Non-Dispersive Infrared*
NIST-SRM	*National Institute of Standards and Technology - Standard Reference Material*
PC	*Personal Computer*
PCA	P*rinted Circuit Assembly*, the PCB with electronic components, ready to use
PC/AT	*Personal Computer / Advanced Technology*
PCB	*Printed Circuit Board*, the bare board without electronic component
PFA	*Perfluoroalkoxy*, an inert polymer; one of the polymers that *Du Pont* markets as *Teflon*®
PLC	*Programmable Logic Controller*, a device that is used to control instruments based on a logic level signal coming from the analyzer
PLD	*Programmable Logic Device*
PLL	*Phase Lock Loop*
PMT	*Photo Multiplier Tube*, a vacuum tube of electrodes that multiply electrons collected and charged to create a detectable current signal
P/N (or PN)	*Part Number*
PSD	*Prevention of Significant Deterioration*
PTFE	*Polytetrafluoroethylene*, a very inert polymer material used to handle gases that may react on other surfaces; one of the polymers that *Du Pont* markets as *Teflon*®
PVC	*Poly Vinyl Chloride*, a polymer used for downstream tubing
Rdg	Reading
RS-232	specification and standard describing a serial communication method between DTE (Data Terminal Equipment) and DCE (Data Circuit-terminating Equipment) devices, using a maximum cable-length of 50 feet
RS-485	specification and standard describing a binary serial communication method among multiple devices at a data rate faster than RS-232 with a much longer distance between

Term	Description/Definition
	the host and the furthest device
SAROAD	*Storage and Retrieval of Aerometric Data*
SLAMS	*State and Local Air Monitoring Network Plan*
SLPM	*Standard Liters Per Minute* of a gas at standard temperature and pressure
STP	*Standard Temperature and Pressure*
TCP/IP	*Transfer Control Protocol / Internet Protocol*, the standard communications protocol for Ethernet devices
TEC	*Thermal Electric Cooler*
TPC	*Temperature/Pressure Compensation*
USB	*Universal Serial Bus*: a standard connection method to establish communication between peripheral devices and a host controller, such as a mouse and/or keyboard and a personal computer or laptop
VARS	*Variables*, the variable settings of the instrument
V-F	*Voltage-to-Frequency*
Z/S	*Zero / Span*

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Teledyne API - Models T100, 100E Series (05036F DCN6650)   *APPENDIX A - Version Specific Software Documentation*
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APPENDIX A - Version Specific Software Documentation Rev 1.0.3 (T-Series)/G6 (E-Series)

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APPENDIX A-1: Software Menu Trees

SAMPLE

TEST[1]   **CAL**   **MSG**[1,2]   **CLR**[1,3]   **SETUP**

<TST   TST>

Only appear if reporting range is set for **AUTO** range mode.

LOW   HIGH

ENTER SETUP PASS: 818

(Primary Setup Menu)

CFG   DAS   RANG   PASS   CLK   MORE

ZERO   SPAN   CONC

(Secondary Setup Menu)

COMM   VARS   DIAG

RANGE
STABIL
STABIL2[4]
RSP
PRES
SAMP FL
PMT
NORM PMT
UV LAMP
UV STB
LAMP RATIO
STR. LGT
DARK PMT
DARK LMP
SLOPE
OFFSET
HVPS
RCELL ON
RCELL TEMP
BOX TEMP
PMT TEMP
IZS TEMP[5]
TEST[6]
TIME

TEST FUNCTIONS
Viewable by user while instrument is in SAMPLE Mode (see *Test Functions* section in manual).

[1] Only appears when warning messages are activated (see section on *Warning Messages* in manual).
[2] Press this key to cycle through list of active warning messages.
[3] Press to clear/erase the warning message currently displayed
[4] T100U/M100EU
[5] Only appears if the IZS valve option is installed.
[6] Only appears if the TEST analog output channel is activated.

Figure A-1:   Basic Sample Display Menu

SAMPLE

TEST[1]   CAL   CALZ   CALS   MSG[1,2]   CLR[1,3]   SETUP

<TST   TST>

Only appears if reporting range is set for **AUTO** range mode.

LOW   HIGH   LOW   HIGH   LOW   HIGH

RANGE
STABIL
STABIL2[4]
RSP[6]
VAC[7]
PRES
SAMP FL
PMT
NORM PMT
UV LAMP
UV STB[4]
LAMP RATIO
STR. LGT
DARK PMT
DARK LMP
SLOPE
OFFSET
HVPS
RCELL ON
RCELL TEMP
BOX TEMP
PMT TEMP
IZS TEMP[5]
TEST[6]
TIME

ZERO   SPAN   CONC   ZERO   SPAN   CONC

ENTER SETUP PASS: 818

(Primary Setup Menu)

CFG   DAS   RANG   PASS   CLK   MORE

(Secondary Setup Menu)

COMM   VARS   DIAG

TEST FUNCTIONS
Viewable by user while instrument is in SAMPLE Mode (see *Test Functions* section in manual).

[1] Only appears when warning messages are activated.
[2] Press to cycle through list of active warning messages.
[3] Press to clear/erase the warning message currently displayed.
[4] T100U/M100EU
[5] Only appears if the IZS valve option is installed.
[6] Only appears if the TEST analog output channel is activated.
[6] Not in T100H/M100EH
[7] T100H/M100EH

Figure A-2:   Sample Display Menu - Units with Z/S Valve or IZS Option installed

Figure A-3: Primary Setup Menu (Except DAS)
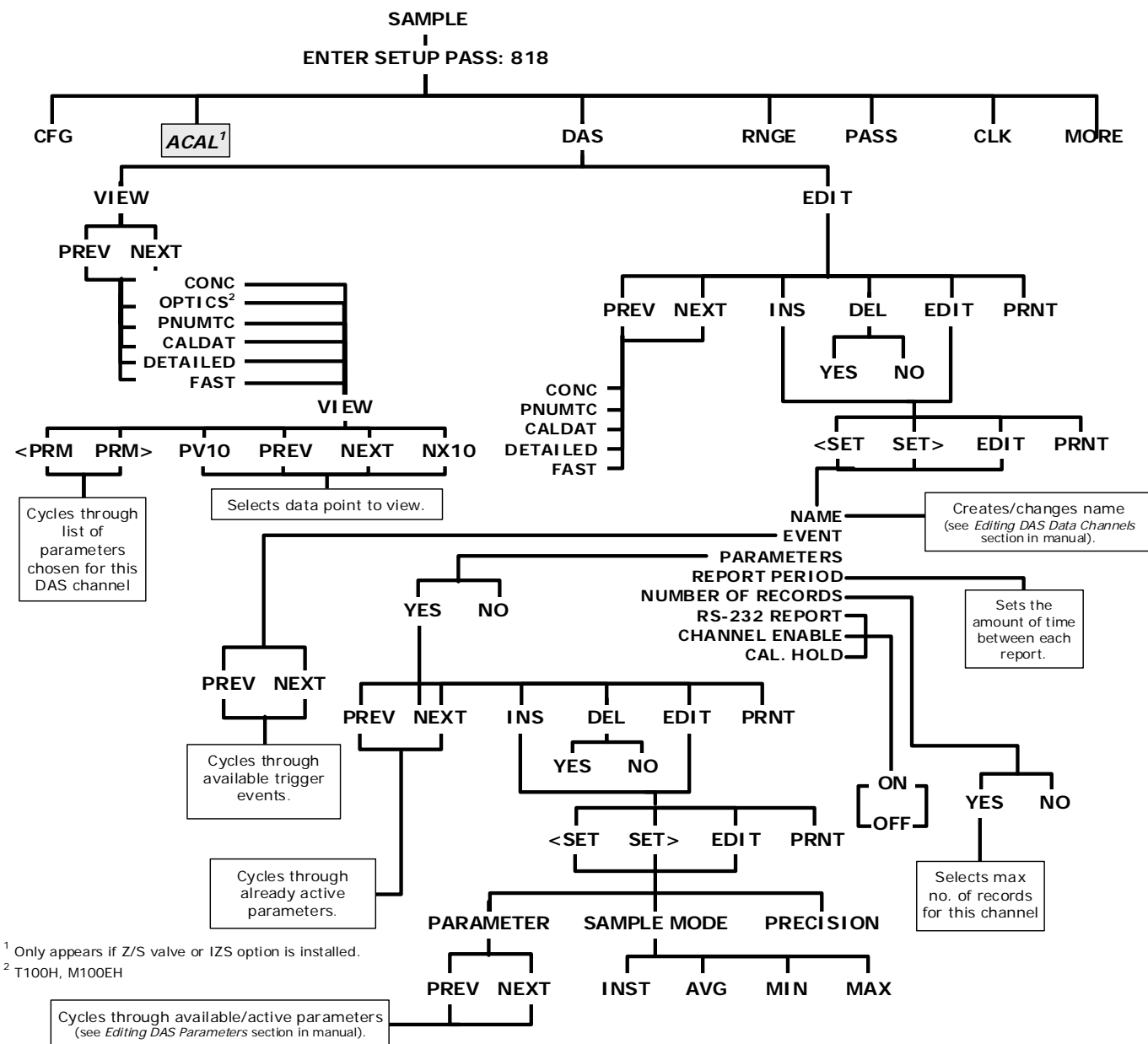
Figure A-4:   Primary Setup Menu (DAS)

[1] Only appears if Z/S valve or IZS option is installed.
[2] T100H, M100EH

SAMPLE

ENTER SETUP PASS: 818

CFG **ACAL[1]** **DAS** **RNGE** **PASS** **CLK** **MORE**

COMM **VARS** **DIAG**

Password required

ID **INET[2]** **COM1 COM2[3]**

Go To INET MENU TREE (Fig A-6)

PREV NEXT JUMP **EDIT PRINT**

DAS_HOLD_OFF
TPC_ENABLE
RCELL_SET
IZS_SET
DYN_ZERO
DYN_SPAN
CONC_PRECISION
CLOCK_ADJ
SERVICE_CLEAR
TIME_SINCE_SVC
SVC_INTERVAL

<SET   SET> **EDIT**

MODE **BAUD RATE TEST PORT**

PREV   NEXT **PREV   NEXT** **TEST**

QUIET
COMPUTER
HESSEN PROTOCOL
E, 8, 1
E, 7, 1
RS-485
SECURITY
MULTIDROP PROTOCOL
ENABLE MODEM
ERROR CHECKING
XON/XOFF HANDSHAKE
HARDWARE HANDSHAKE
HARDWARE FIFO
COMMAND PROMPT

ON

OFF

300
1200
2400
4800
9600
19200
38400
57600
115200

**Go To
DIAG MENU TREE**
(Fig A-8)

[1] Only appears if Z/S valve or IZS option is installed.
[2] M100E, M100EU, M100EH: Only appears when the
  ENABLE INTERNET mode is enabled.
[3] M100E, M100EU, M100EH: Disappears when INET option
  is enabled.

Figure A-5:   Secondary Setup Menu (COMM & VARS)

SETUP

ENTER SETUP PASS: 818

CFG   *ACAL[1]*   DAS   RNGE   PASS   CLK   MORE

COMM   VARS   DIAG

Password required

ID   COM1

PREV   NEXT   JUMP   EDIT   PRINT

INET[2]

<SET   SET>   EDIT

**COMM
MENU TREE**
(Fig A-5)

DHCP

**INSTRUMENT IP
GATEWAY IP
SUBNET MASK**

**TCP PORT[3]
HOSTNAME[4]**

**VARS
MENU TREE**
(Fig A-5)

ON

OFF   EDIT   **INSTRUMENT IP[5]
GATEWAY IP[5]
SUBNET MASK[5]
TCP PORT[3]**

**Go To
DIAG MENU TREE**
(Fig A-8)
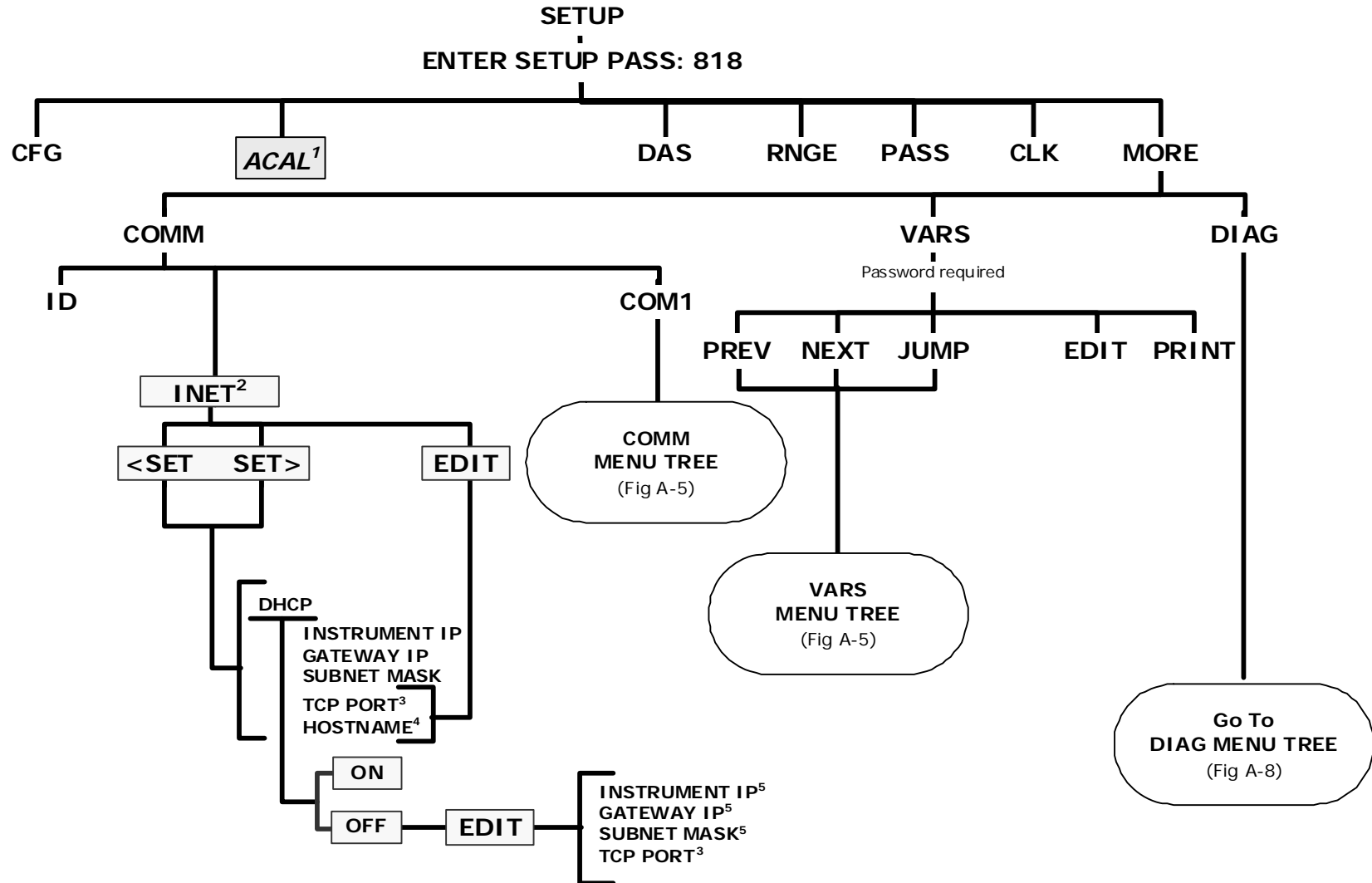
[1] Only appears if a valve option is installed.

[2] M100E, M100EU, M100EH: Only appears when the Ethernet card (option 63) is installed.

[3] M100E, M100EU, M100EH: Although **TCP PORT** is editable regardless of the **DHCP** state, do not change the setting for this property unless instructed to by Teledyne Instruments Customer Service personnel.

[4] **HOST NAME** is only editable when DHCP is **ON**.

[5] **INSTRUMENT IP**, **GATEWAY IP** & **SUBNET MASK** are only editable when DHCP is **OFF**.

Figure A-6:   Secondary Setup, COMM — INET (Ethernet) Menu

SETUP

ENTER SETUP PASS: 818

CFG   *ACAL[1]*   DAS   RNGE   PASS   CLK   MORE

COMM   VARS   DIAG

ID   HESN[2]   COM1 COM2

See
Fig A-5

See
Fig A-8

<SET   SET>   EDIT

See
Fig A-5

VARIATION   RESPONSE MODE   GAS LIST   STATUS FLAGS

TYPE 1
TYPE 2

BCC   TEXT   CMD

PREV NEXT   INS   DEL   EDIT   PRNT

YES   NO

(see *Hessen Protocol Gas ID section in manual*)

SO2, 110, REPORTED

GAS TYPE
GAS ID
REPORTED

ON
OFF

PMT DET WARNING
UV LAMP WARNING[1]
DARK CAL WARNING
IZS TEMP WARNING
BOX TEMP WARNING
PMT TEMP WARNING
RCELL TEMP WARNING
SAMPLE FLOW WARNING
SAMPLE PRESS WARNING
VACUUM PRESS WARN[4]
HVPS WARNING
SYSTEM RESET
REAR BOARD NOT DET
RELAY BOARD WARN
FRONT PANEL WARN
ANALOG CAL WARNING
CANNOT DYN ZERO
CANNOT DYN SPAN
INVALID CONC
ZERO CAL
LOW SPAN CAL[4]
SPAN CAL
MP CAL
MANUAL MODE
INVALID
PPB[3]
PPM[3]
UGM[3]
MGM[3]
SO2 ALARM 1
SO@ ALARM 2

[1] Only appears if a valve option is installed.
[2] Only appears when the **HESSEN** mode is enabled.
[3] See *Setting Hessen Protocol Status Flags* section in
   manual for Flag Assignments.
[4] T100H, M100EH

Figure A-7:   Secondary Setup Menu - HESSEN Submenu

SAMPLE
ENTER SETUP PASS: 818

CFG   ACAL[1]   DAS   RNGE   PASS   CLK   MORE

COMM   VARS   **DIAG**

PMT [5]
CALIBRATION

PREV   NEXT

SIGNAL I/O   ANALOG OUTPUT   ANALOG I/O CONFIGURATION   OPTIC TEST   ELECTRICAL TEST   LAMP CALIBRATION   PRESSURE CALIBRATION   FLOW CALIBRATION   TEST CHANNEL OUTPUT

PREV   NEXT   ENTR   ENTR   ENTR   ENTR   ENTR   ENTR

Start step Test   Starts Test   Starts Test   Starts Test   Starts Test   Starts Test

0) EXT ZERO CAL
1) EXT SPAN CAL
   EXT LOW SPAN [3]
2) MAINT MODE
3) LANG2 SELECT
4) SAMPLE LED
5) CAL LED
6) FAULT LED
7) AUDIBLE BEEPER
8) ELEC TEST
9) OPTIC TEST
10) DARK TEST [4]
11) PREAMP RANGE HI
12) ST SYSTEM OK
13) ST CONC VALID
14) ST HIGH RANGE
15) ST ZERO CAL
16) ST SPAN CAL
17) ST DIAG MODE
    ST LOW SPAN CAL [3]
18) ST LAMP ALARM
19) ST DARK CAL ALARM
20) ST FLOW ALARM
21) ST PRESS ALARM
22) SR TEMP ALARM
23) ST HVPS ALARM
24) ST SYSTEM OK2
25) ST CONC ALARM 1
26) ST CONC ALARM 2
27) ST HIGH RANGE 2
28) RELAY WATCHDOG
29) RCELL HEATER
30) IZS HEATER [2]
31) CAL VALVE
32) SPAN VALVE
33) PMT SIGNAL
    LOW SPAN VALVE [3]
34) ZERO VALVE [1]
35) DARK SHUTTER

36   INTERNAL ANALOG
↓   VOLTAGE SIGNALS
54   (see Appendix A)

AOUTS CALIBRATED

CAL

CONC OUT 1
CONC OUT 2
TEST OUTPUT

<SET   SET>

EDIT

<SET   SET>

RANGE   REC OFFSET   AUTO CAL   CALIBRATED

ON / OFF

0.1V   1V   5V   10V   CURR

ON / OFF

CAL

NONE
PMT READING
UV READING
SAMPLE PRESSURE
SAMPLE FLOW
RCELL TEMP
CHASSIS TEMP
IZS TEMP[2]
PMT TEMP
HVPS VOLTAGE

[1] Only appears if valve option is installed.
[2] Only relevant to analyzers with IZS options installed.
[3] T100H, M100EH
[4] T100, T100U, M100E, M100EU
[5] T100U, M100EU

Figure A-8:   Secondary Setup Menu (DIAG)

APPENDIX A-2: Setup Variables For Serial I/O

Table A-1:   Setup Variables

SETUP VARIABLE	NUMERIC UNITS	DEFAULT VALUE	VALUE RANGE	DESCRIPTION
Low Access Level Setup Variables (818 password)				
DAS_HOLD_OFF	Minutes	15	0.5–20	Duration of DAS hold off period.
TPC_ENABLE	—	ON	OFF, ON	ON enables temperature and pressure compensation; OFF disables it.
RCELL_SET	ºC	50 Warnings: 45–55	30–70	Reaction cell temperature set point and warning limits.
IZS_SET [1]	ºC	50 Warnings: 45–55	30–70	IZS temperature set point and warning limits.
DYN_ZERO	—	OFF	OFF, ON	ON enables contact closure dynamic zero; OFF disables it.
DYN_SPAN	—	OFF	OFF, ON	ON enables contact closure dynamic span; OFF disables it.
CONC_PRECISION	—	3	AUTO, 0, 1, 2, 3, 4	Number of digits to display to the right of the decimal point for concentrations on the display. Enclose value in double quotes (") when setting from the RS-232 interface.
REM_CAL_DURATION [17]	Minutes	20	1–120	Duration of automatic calibration initiated from TAI protocol.
CLOCK_ADJ	Sec./Day	0	-60–60	Time-of-day clock speed adjustment.
SERVICE_CLEAR	—	OFF	OFF ON	ON resets the service interval timer.
TIME_SINCE_SVC	Hours	0	0–500000	Time since last service.
SVC_INTERVAL	Hours	0	0–100000	Sets the interval between service reminders.
Medium Access Level Setup Variables (929 password)				
LANGUAGE_SELECT	—	ENGL	ENGL, SECD, EXTN	Selects the language to use for the user interface. Enclose value in double quotes (") when setting from the RS-232 interface.
MAINT_TIMEOUT	Hours	2	0.1–100	Time until automatically switching out of software-controlled maintenance mode.
CONV_TIME	—	33 MS	33 MS, 66 MS, 133 MS, 266 MS, 533 MS, 1 SEC, 2 SEC	Conversion time for PMT and UV detector channels. Enclose value in double quotes (") when setting from the RS-232 interface.

SETUP VARIABLE	NUMERIC UNITS	DEFAULT VALUE	VALUE RANGE	DESCRIPTION
DWELL_TIME	Seconds	1	0.1–10	Dwell time before taking each sample.
FILT_SIZE	Samples	240, 30 [3], 480 [12]	1–1000	Moving average filter size.
FILT_ASIZE	Samples	20, 6 [3]	1–100	Moving average filter size in adaptive mode.
FILT_DELTA	PPM	0.02, 10 [3], 0.005 [12]	0.001–0.1, 1–100[3]	Absolute change to trigger adaptive filter.
FILT_PCT	%	5, 10 [2], 1 [12]	1–100	Percent change to trigger adaptive filter.
FILT_DELAY	Seconds	180	0–300	Delay before leaving adaptive filter mode.
FILT_ADAPT	—	ON	OFF, ON	ON enables adaptive filter; OFF disables it.
NEG_CONC_SUPPRESS	—	OFF	OFF, ON	ON pegs negative concentrations at zero; OFF permits negative concentrations
DIL_FACTOR	—	1	0.1–1000	Dilution factor if dilution enabled with *FACTORY_OPT* variable.
AGING_ENABLE [18]	—	OFF	ON, OFF	ON enables aging offset and slope compensation.
AGING_OFFSET_RATE [18]	mV/day	0	-1.0–1.0	Aging offset rate of change per day.
AGING_SLOPE_RATE [18]	Change/ day	0	-0.01–0.01	Aging slope rate of change per day.
CO2_DWELL [11]	Seconds	1	0.1–30	Dwell time before taking each sample.
CO2_FILT_ADAPT [11]	—	ON	ON, OFF	ON enables CO_2 adaptive filter; OFF disables it.
CO2_FILT_SIZE [11]	Samples	48	1–300	CO_2 moving average filter size in normal mode.
CO2_FILT_ASIZE [11]	Samples	12	1–300	CO_2 moving average filter size in adaptive mode.
CO2_FILT_DELTA [11]	%	2	0.1–10	Absolute change in CO_2 concentration to shorten filter.
CO2_FILT_PCT [11]	%	10	0.1–100	Relative change in CO_2 concentration to shorten filter.
CO2_FILT_DELAY [11]	Seconds	90	0–300	Delay before leaving CO_2 adaptive filter mode.
CO2_DIL_FACTOR [11]	—	1	0.1–1000	Dilution factor for CO_2. Used only if is dilution enabled with *FACTORY_OPT* variable.
CO2_STD_CELL_TEMP [11]	ºK	323	1–500	Standard CO_2 cell temperature for temperature compensation.
CO2_STD_CELL_PRESS [11]	"Hg	28.50	1.00–50.00	Standard CO_2 cell pressure for pressure compensation.
O2_DWELL [10]	Seconds	1	0.1–30	Dwell time before taking each sample.

SETUP VARIABLE	NUMERIC UNITS	DEFAULT VALUE	VALUE RANGE	DESCRIPTION
O2_FILT_ADAPT [10]	—	ON	ON, OFF	ON enables O_2 adaptive filter; OFF disables it.
O2_FILT_SIZE [10]	Samples	60	1–500	O_2 moving average filter size in normal mode.
O2_FILT_ASIZE [10]	Samples	10	1–500	O_2 moving average filter size in adaptive mode.
O2_FILT_DELTA [10]	%	2	0.1–100	Absolute change in O_2 concentration to shorten filter.
O2_FILT_PCT [10]	%	2	0.1–100	Relative change in O_2 concentration to shorten filter.
O2_FILT_DELAY [10]	Seconds	20	0–300	Delay before leaving O_2 adaptive filter mode.
O2_DIL_FACTOR [10]	—	1	0.1–1000	Dilution factor for O_2. Used only if is dilution enabled with *FACTORY_OPT* variable.
O2_CELL_SET [10]	ºC	50 Warnings: 45–55	30–70	O_2 sensor cell temperature set point and warning limits.
O2_STD_CELL_TEMP [10]	ºK	323	1–500	Standard O_2 cell temperature for temperature compensation.
O2_STD_CELL_PRESS [10]	"Hg	28.50	1.00–50.00	Standard O_2 cell pressure for pressure compensation.
USER_UNITS	—	PPB, PPM [3]	PPB, PPM, UGM, MGM, PPM [3], MGM [3]	Concentration units for user interface. Enclose value in double quotes (") when setting from the RS-232 interface.
LAMP_DRIVE [6]	mV	5000	0–5000	Lamp power setting.
LAMP_CAL	mV	3500	1000–5000	Last calibrated UV lamp reading.
LAMP_GAIN	—	0.95	0.5–1.5	UV lamp compensation attenuation factor.
BXTEMP_TPC_GAIN	—	1, 0 [12]	0–10	Box temperature compensation attenuation factor.
SPRESS_TPC_GAIN	—	1	0–10	Sample pressure compensation attenuation factor.
PMT_TARG_CONC [12]	Conc	400	0.01–9999.99	Target SO_2 concentration during PMT calibration.
PMT_UPDATE_PERIOD [12]	Seconds	10	1–100	Period between HVPS gain updates during PMT calibration.
PMT_CAL_TIMEOUT [12]	Minutes	30	1–100	Maximum time for PMT calibration to succeed.
HVPS_ADJUST [12]	—	0	0–200	HVPS gain adjustment.
HVPS_INTEG [12]	Gain	5	0–500	Integral coefficient for adjusting HVPS gain during PMT calibration.
HVPS_STABIL [12]	—	1	0.1–10	HVPS gain must stabilize to within this limit for PMT calibration to succeed.
PMT_ADJUST [12]	—	0	0–65535	PMT gain adjustment.

SETUP VARIABLE	NUMERIC UNITS	DEFAULT VALUE	VALUE RANGE	DESCRIPTION
SLOPE_CONST	—	8, 6.25 [3]	0.1–10	Constant to make visible slope close to 1.
DARK_ENABLE	—	ON, OFF [12]	OFF, ON	ON enables PMT/UV dark calibration; OFF disables it.
DARK_FREQ	Minutes	30, 720 [3]	0.1–1440	Dark calibration period.
DARK_PRE_DWELL	Seconds	10	1–60	Dwell time after closing dark shutter or turning off lamp or selecting preamp range.
DARK_POST_DWELL	Seconds	10, 30 [3]	1–180	Dwell time after opening dark shutter or turning on lamp.
DARK_SAMPLES	Samples	5	1–10	Number of dark samples to average.
DARK_FSIZE	Samples	2	1–100	Dark offset moving average filter size.
DARK_LIMIT	mV	200, 400 [3]	0–1000	Maximum dark offset allowed.
SO2_TARG_ZERO1	Conc	0	-100–999.99	Target SO_2 concentration during zero calibration of range 1.
SO2_SPAN1	Conc	400, 4000 [3]	0.01–9999.99	Target SO_2 concentration during span calibration of range 1.
SO2_SLOPE1	PPB/mV, PPM/mV [3]	1	0.25–4	SO_2 slope for range 1.
SO2_OFFSET1	mV	0	-55000–55000	SO_2 offset for range 1.
SO2_BACKGROUND1 [4]	PPM	0	-10000–10000	SO_2 background concentration for range 1.
SO2_TARG_ZERO2	Conc	0	-100–999.99	Target SO_2 concentration during zero calibration of range 2.
SO2_SPAN2	Conc	400, 4000 [3]	0.01–9999.99	Target SO_2 concentration during span calibration of range 2.
SO2_SLOPE2	PPB/mV, PPM/mV [3]	1	0.25–4	SO_2 slope for range 2.
SO2_OFFSET2	mV	0	-55000–55000	SO_2 offset for range 2.
SO2_BACKGROUND2 [4]	PPM	0	-10000–10000	SO_2 background concentration for range 2.
CO2_TARG_SPAN_CONC [11]	%	12	0.1–1000	Target CO_2 concentration during span calibration.
CO2_SLOPE [11]	—	1	0.5–5	CO_2 slope.
CO2_OFFSET [11]	%	0	-10–10	CO_2 offset.
O2_TARG_SPAN_CONC [10]	%	20.95	0.1–100	Target O_2 concentration during span calibration.
O2_SLOPE [10]	—	1	0.5–2	O_2 slope.
O2_OFFSET [10]	%	0	-10–10	O_2 offset.
RANGE_MODE	—	SNGL	SNGL, DUAL, AUTO	Range control mode. Enclose value in double quotes (") when setting from the RS-232 interface.

SETUP VARIABLE	NUMERIC UNITS	DEFAULT VALUE	VALUE RANGE	DESCRIPTION
PHYS_RANGE1	PPM	2, 500 [3]	0.1–2500, 5–10000 [3]	Low pre-amp range.
PHYS_RANGE2	PPM	22, 5500 [3]	0.1–2500, 5–10000 [3]	High pre-amp range.
CONC_RANGE1	Conc	500, 5000 [3]	0.1–50000	D/A concentration range 1.
CONC_RANGE2	Conc	500, 5000 [3]	0.1–50000	D/A concentration range 2.
CO2_RANGE [11]	%	15	0.1–500	CO_2 concentration range.
O2_RANGE [10]	%	100	0.1–500	O_2 concentration range.
SAMP_FLOW_SET	cc/m	700, 250 [1+9] Warnings: 350–1200, 175–325 [1+9]	0–6000	Sample flow set point for flow calculation and warning limits.
SAMP_FLOW_SLOPE	—	1	0.5–1.5	Sample flow slope correction factor (adjusted flow = measured flow x slope).
VAC_SAMP_RATIO [3]	—	0.53	0.1–2	Maximum vacuum pressure / sample pressure ratio for valid sample flow calculation.
SAMP_PRESS_SET	"Hg	29.92 Warnings: 15–35	0–100	Sample pressure set point for pressure compensation and warning limits.
VAC_PRESS_SET [3]	"Hg	6 Warnings: 3–10	0–100	Vacuum pressure set point for pressure compensation and warning limits.
BOX_SET	ºC	30 Warnings: 8–50	5–60	Box temperature warning limits. Set point is not used.
PMT_SET	ºC	7, 15 [12] Warnings: 2–12, 2–20 [12]	0–40	PMT temperature set point and warning limits.

SETUP VARIABLE	NUMERIC UNITS	DEFAULT VALUE	VALUE RANGE	DESCRIPTION
RS232_MODE	BitFlag	0	0–65535	RS-232 COM1 mode flags. Add values to combine flags. 1 = quiet mode 2 = computer mode 4 = enable security 8 = enable hardware handshaking 16 = enable Hessen protocol [8] 32 = enable multi-drop 64 = enable modem 128 = ignore RS-232 line errors 256 = disable XON / XOFF support 512 = disable hardware FIFOs 1024 = enable RS-485 mode 2048 = even parity, 7 data bits, 1 stop bit 4096 = enable command prompt 8192 = even parity, 8 data bits, 1 stop bit 16384 = enable dedicated MODBUS ASCII protocol 32678 = enable dedicated MODBUS RTU or TCP protocol 16384 = enable TAI protocol [17]
BAUD_RATE	—	115200	300, 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200	RS-232 COM1 baud rate. Enclose value in double quotes (") when setting from the RS-232 interface.
MODEM_INIT	—	"AT Y0 &D0 &H0 &I0 S0=2 &B0 &N6 &M0 E0 Q1 &W0"	Any character in the allowed character set. Up to 100 characters long.	RS-232 COM1 modem initialization string. Sent verbatim plus carriage return to modem on power up or manually. Enclose value in double quotes (") when setting from the RS-232 interface.
RS232_MODE2	BitFlag	0	0–65535	RS-232 COM2 mode flags. *(Same settings as RS232_MODE.)*

SETUP VARIABLE	NUMERIC UNITS	DEFAULT VALUE	VALUE RANGE	DESCRIPTION
BAUD_RATE2	—	19200	300, 1200, 2400, 4800, 9600, 19200, 38400, 57600, 115200	RS-232 COM2 baud rate. Enclose value in double quotes (") when setting from the RS-232 interface.
MODEM_INIT2	—	"AT Y0 &D0 &H0 &I0 S0=2 &B0 &N6 &M0 E0 Q1 &W0"	Any character in the allowed character set. Up to 100 characters long.	RS-232 COM2 modem initialization string. Sent verbatim plus carriage return to modem on power up or manually. Enclose value in double quotes (") when setting from the RS-232 interface.
RS232_PASS	Password	940331	0–999999	RS-232 log on password.
MACHINE_ID	ID	100	0–9999	Unique ID number for instrument.
COMMAND_PROMPT	—	"Cmd> "	Any character in the allowed character set. Up to 100 characters long.	RS-232 interface command prompt. Displayed only if enabled with *RS232_MODE* variable. Enclose value in double quotes (") when setting from the RS-232 interface.
TEST_CHAN_ID	—	NONE	NONE, PMT READING, UV READING, VACUUM PRESSURE[3], SAMPLE PRESSURE, SAMPLE FLOW, RCELL TEMP, O2 CELL TEMP [10], CHASSIS TEMP, IZS TEMP [1], PMT TEMP, HVPS VOLTAGE	Diagnostic analog output ID. Enclose value in double quotes (") when setting from the RS-232 interface.
REMOTE_CAL_MODE	—	LOW	LOW, HIGH, CO2 [11], O2 [10]	Range to calibrate during contact-closure and Hessen calibration. Enclose value in double quotes (") when setting from the RS-232 interface.
PASS_ENABLE	—	OFF	OFF, ON	ON enables passwords; OFF disables them.
RCELL_CYCLE	Seconds	2	0.5–30	Reaction cell temperature control cycle period.
RCELL_PROP	1/ºC	0.3 (prop. band = 3.3 ºC)	0–10	Reaction cell temperature PID proportional coefficient.

SETUP VARIABLE	NUMERIC UNITS	DEFAULT VALUE	VALUE RANGE	DESCRIPTION
RCELL_INTEG	—	0.005	0–10	Reaction cell temperature PID integral coefficient.
RCELL_DERIV	—	0.5	0–10	Reaction cell temperature PID derivative coefficient.
O2_CELL_CYCLE [10]	Seconds	10	0.5–30	O_2 cell temperature control cycle period.
O2_CELL_PROP [10]	—	1	0–10	O_2 cell PID temperature control proportional coefficient.
O2_CELL_INTEG [10]	—	0.1	0–10	O_2 cell PID temperature control integral coefficient.
O2_CELL_DERIV [10]	—	0 (disabled)	0–10	O_2 cell PID temperature control derivative coefficient.
IZS_CYCLE [1]	Seconds	2	0.5–30	IZS temperature control cycle period.
IZS_PROP [1]	1/ºC	1 (prop. band = 1 ºC)	0–10	IZS temperature PID proportional coefficient.
IZS_INTEG [1]	—	0.03	0–10	IZS temperature PID integral coefficient.
IZS_DERIV [1]	—	0	0–10	IZS temperature PID derivative coefficient.
HVPS_SET	Volts	650, 550 [3] Warnings: 400–900, 400–700 [3]	0–2000	High voltage power supply warning limits. Set point is not used.
MAX_PMT_DETECTOR	mV	4995	0–5000	PMT detector maximum warning limit.
PHOTO_ABS_LIMITS [1]	mV	450 Warnings: 125–625	0–5000	Pre-amplified UV lamp minimum/maximum warning limits. Set point is not used.
UV_LAMP_LIMITS	mV	3500 Warnings: 1000–4995	0–5000	UV lamp minimum/maximum warning limits. Set point is not used.
ELEC_TEST_LEVEL [12]	—	0	0–65535	Electrical test level setting.
OPTIC_TEST_LEVEL [12]	—	0	0–65535	Optical test level setting.
CONC_LIN_ENABLE [3]	—	ON	OFF, ON	*ON* enables concentration linearization; *OFF* disables it.
STAT_REP_PERIOD [17]	Seconds	1	0.5–120	TAI protocol status message report period.
SERIAL_NUMBER	—	"00000000 "	Any character in the allowed character set. Up to 100 characters long.	Unique serial number for instrument. Enclose value in double quotes (") when setting from the RS-232 interface.
DISP_INTENSITY	—	HIGH	HIGH, MED, LOW, DIM	Front panel display intensity. Enclose value in double quotes (") when setting from the RS-232 interface.
I2C_RESET_ENABLE	—	ON	OFF, ON	I^2C bus automatic reset enable.

SETUP VARIABLE	NUMERIC UNITS	DEFAULT VALUE	VALUE RANGE	DESCRIPTION
CLOCK_FORMAT	—	"TIME=%H:%M:%S"	Any character in the allowed character set. Up to 100 characters long.	Time-of-day clock format flags. Enclose value in double quotes (") when setting from the RS-232 interface. "%a" = Abbreviated weekday name. "%b" = Abbreviated month name. "%d" = Day of month as decimal number (01 – 31). "%H" = Hour in 24-hour format (00 – 23). "%I" = Hour in 12-hour format (01 – 12). "%j" = Day of year as decimal number (001 – 366). "%m" = Month as decimal number (01 – 12). "%M" = Minute as decimal number (00 – 59). "%p" = A.M./P.M. indicator for 12-hour clock. "%S" = Second as decimal number (00 – 59). "%w" = Weekday as decimal number (0 – 6; Sunday is 0). "%y" = Year without century, as decimal number (00 – 99). "%Y" = Year with century, as decimal number. "%%" = Percent sign.
ALARM_TRIGGER [13]	Cycles	3	1–100	Number of times concentration must exceed limit to trigger alarm.

SETUP VARIABLE	NUMERIC UNITS	DEFAULT VALUE	VALUE RANGE	DESCRIPTION
FACTORY_OPT	BitFlag	0	0–65535	Factory option flags. Add values to combine flags. 1 = enable dilution factor 2 = zero/span valves installed 4 = IZS installed (implies zero/span valves installed) 8 = low span valve installed 16 = display units in concentration field 32 = enable software-controlled maintenance mode 64 = enable lamp power analog output 128 = enable switch-controlled maintenance mode 256 = compute only offset during zero calibration 1024 = enable high flow rate sensor 2048 = enable Internet option 4096 = enable pre-amplified UV lamp monitoring 8192 = enable non-zero offset calibration 16384 = enable pressurized zero calibration 32768 = enable pressurized span calibration

1. T100/M100E.
2. M100ES.
3. T100H/M100EH.
4. Background concentration compensation option (6400E/6400EH).
6. Engineering firmware only.
7. iChip option.
8. Must power-cycle instrument for these options to fully take effect.
9. Low span option.
10. O_2 option.
11. CO_2 option.
12. T100U/M100EU.
13. Concentration alarm option.
17. TAI protocol
18. Aging Compensation option.
99. Obsolete.

APPENDIX A-3: Warnings and Test Functions

Table A-2:   Warning Messages

NAME	MESSAGE TEXT	DESCRIPTION
Warnings		
WSYSRES	SYSTEM RESET	Instrument was power-cycled or the CPU was reset.
WDATAINIT	DATA INITIALIZED	Data storage was erased.
WCONFIGINIT	CONFIG INITIALIZED	Configuration storage was reset to factory configuration or erased.
WSO2ALARM1 [7]	SO2 ALARM 1 WARN	SO_2 concentration alarm limit #1 exceeded
WSO2ALARM2 [7]	SO2 ALARM 2 WARN	SO_2 concentration alarm limit #2 exceeded
WO2ALARM1 [10+7]	O2 ALARM 1 WARN	O_2 concentration alarm limit #1 exceeded
WO2ALARM2 [10+7]	O2 ALARM 2 WARN	O_2 concentration alarm limit #2 exceeded
WCO2ALARM1 [11+7]	CO2 ALARM 1 WARN	CO_2 concentration alarm limit #1 exceeded
WCO2ALARM2 [11+7]	CO2 ALARM 2 WARN	CO_2 concentration alarm limit #2 exceeded
WPMT	PMT DET WARNING	PMT detector outside of warning limits specified by *DETECTOR_LIMIT* variable.
WUVLAMP	UV LAMP WARNING	UV lamp reading outside of warning limits specified by *DETECTOR_LIMIT* variable.
WSAMPFLOW	SAMPLE FLOW WARN	Sample flow outside of warning limits specified by *SAMP_FLOW_SET* variable.
WSAMPPRESS	SAMPLE PRESS WARN	Sample pressure outside of warning limits specified by *SAMP_PRESS_SET* variable.
WVACPRESS [5]	VACUUM PRESS WARN	Vacuum pressure outside of warning limits specified by *VAC_PRESS_SET* variable.
WBOXTEMP	BOX TEMP WARNING	Chassis temperature outside of warning limits specified by *BOX_SET* variable.
WRCELLTEMP	RCELL TEMP WARNING	Reaction cell temperature outside of warning limits specified by *RCELL_SET* variable.
WO2CELLTEMP [10]	O2 CELL TEMP WARN	O_2 sensor cell temperature outside of warning limits specified by *O2_CELL_SET* variable.
WIZSTEMP	IZS TEMP WARNING	IZS temperature outside of warning limits specified by *IZS_SET* variable.
WPMTTEMP	PMT TEMP WARNING	PMT temperature outside of warning limits specified by *PMT_SET* variable.
WDARKCAL	DARK CAL WARNING	Dark offset above limit specified by *DARK_LIMIT* variable.
WHVPS	HVPS WARNING	High voltage power supply output outside of warning limits specified by *HVPS_SET* variable.
WDYNZERO	CANNOT DYN ZERO	Contact closure zero calibration failed while *DYN_ZERO* was set to *ON*.
WDYNSPAN	CANNOT DYN SPAN	Contact closure span calibration failed while *DYN_SPAN* was set to *ON*.
WREARBOARD	REAR BOARD NOT DET	Rear board was not detected during power up.
WRELAYBOARD	RELAY BOARD WARN	Firmware is unable to communicate with the relay board.

NAME	MESSAGE TEXT	DESCRIPTION
WFRONTPANEL [12]	FRONT PANEL WARN	Firmware is unable to communicate with the front panel.
WANALOGCAL	ANALOG CAL WARNING	The A/D or at least one D/A channel has not been calibrated.
[1] The name is used to request a message via the RS-232 interface, as in "T BOXTEMP".		
[2] Engineering software.		
[3] Current instrument units.		
[4] T100/M100E.		
[5] T100H/M100EH.		
[6] T100U/M100EU.		
[7] Concentration alarm option.		
[10] O_2 option.		
[11] CO_2 option.		
[12] Applies to E-Series.		

Table A-3:   Test Functions

TEST FUNCTION	MESSAGE TEXT	DESCRIPTION
Test Measurements		
RANGE	RANGE=500.0 PPB [3] SO2 RNG=500.0 PPB [3, 10, 11]	D/A range in single or auto-range modes.
RANGE1	RANGE1=500.0 PPB [3] SO2 RN1=500.0 PPB [3, 10, 11]	D/A #1 range in independent range mode.
RANGE2	RANGE2=500.0 PPB [3] SO2 RN2=500.0 PPB [3, 10, 11]	D/A #2 range in independent range mode.
CO2RANGE	CO2 RNG=100 PCT [11]	D/A range for CO_2 concentration.
O2RANGE	O2 RNG=100 PCT [10]	D/A range for O_2 concentration
STABILITY	STABIL=0.0 PPB [3] SO2 STB=0.0 PPB [3, 10] O2 STB=0.0 PCT [10] CO2 STB=0.0 PCT [11]	Concentration stability #1.
STABILITY2 [6]	STABIL2=0.0 PPB [3] SO2 STB2=0.0 PPB [3, 10] O2 STB2=0.0 PCT [10] CO2 STB2=0.0 PCT [11]	Concentration stability #2.
RESPONSE [2]	RSP=1.11(0.00) SEC	Instrument response. Length of each signal processing loop. Time in parenthesis is standard deviation.
VACUUM [5]	VAC=9.1 IN-HG-A	Vacuum pressure.
SAMPPRESS	PRES=29.9 IN-HG-A	Sample pressure.
SAMPFLOW	SAMP FL=700 CC/M	Sample flow rate.
PMTDET	PMT=762.5 MV	Raw PMT reading.
NORMPMTDET	NORM PMT=742.9 MV	PMT reading normalized for temperature, pressure, auto-zero offset, but not range.
UVDET	UV LAMP=3457.6 MV	UV lamp reading.
STABILITYUV [6]	UV STB=5.607 MV	UV lamp stability reading.
LAMPRATIO	LAMP RATIO=100.0 %	UV lamp ratio of current reading divided by calibrated reading.
STRAYLIGHT	STR. LGT=0.1 PPB	Stray light offset.
DARKPMT	DRK PMT=19.6 MV	PMT dark offset.
DARKLAMP	DRK LMP=42.4 MV	UV lamp dark offset.
SLOPE	SLOPE=1.061	Slope for current range, computed during zero/span calibration.
OFFSET	OFFSET=250.0 MV	Offset for current range, computed during zero/span calibration.
CO2SLOPE [11]	CO2 SLOPE=1.0000	CO_2 slope, computed during zero/span calibration.
CO2OFFSET [11]	CO2 OFFSET=0.00 %	CO_2 offset, computed during zero/span calibration.
O2SLOPE [10]	O2 SLOPE=0.980	O_2 slope, computed during zero/span calibration.
O2OFFSET [10]	O2 OFFSET=1.79 %	O_2 offset, computed during zero/span calibration.
HVPS	HVPS=650 VOLTS	High voltage power supply output.
RCELLDUTY	RCELL ON=0.00 SEC	Reaction cell temperature control duty cycle.
RCELLTEMP	RCELL TEMP=52.1 C	Reaction cell temperature.
O2CELLTEMP [10]	O2 CELL TEMP=50.2 C	O_2 sensor cell temperature.
BOXTEMP	BOX TEMP=35.5 C	Internal chassis temperature.

TEST FUNCTION	MESSAGE TEXT	DESCRIPTION
PMTTEMP	PMT TEMP=7.0 C	PMT temperature.
IZSDUTY	IZS ON=0.00 SEC	IZS temperature control duty cycle.
IZSTEMP	IZS TEMP=52.2 C	IZS temperature.
SO2	SO2=261.4 PPB	SO_2 concentration for current range.
CO2 [11]	CO2=0.00 PCT	CO_2 concentration.
O2 [10]	O2=0.00 PCT	O_2 concentration.
TESTCHAN	TEST=3721.1 MV	Value output to *TEST_OUTPUT* analog output, selected with *TEST_CHAN_ID* variable.
CLOCKTIME	TIME=10:38:27	Current instrument time of day clock.
XIN1 [12]	AIN1=37.15 EU	External analog input 1 value in engineering units.
XIN2 [12]	AIN2=37.15 EU	External analog input 2 value in engineering units.
XIN3 [12]	AIN3=37.15 EU	External analog input 3 value in engineering units.
XIN4 [12]	AIN4=37.15 EU	External analog input 4 value in engineering units.
XIN5 [12]	AIN5=37.15 EU	External analog input 5 value in engineering units.
XIN6 [12]	AIN6=37.15 EU	External analog input 6 value in engineering units.
XIN7 [12]	AIN7=37.15 EU	External analog input 7 value in engineering units.
XIN8 [12]	AIN8=37.15 EU	External analog input 8 value in engineering units.

[1] The name is used to request a message via the RS-232 interface, as in "T BOXTEMP".

[2] Engineering software.

[3] Current instrument units.

[4] T100/M100E.

[5] T100H/M100EH.

[6] T100U/M100EU.

[7] Concentration alarm option.

[10] O_2 option.

[11] CO_2 option.

APPENDIX A-4: Signal I/O Definitions

Table A-4:   T100/M100E Signal I/O Definitions

SIGNAL NAME	BIT OR CHANNEL NUMBER	DESCRIPTION
Internal inputs, U7, J108, pins 9–16 = bits 0–7, default I/O address 322 hex		
	0–7	Spare
AUX board digital outputs, default I^{2}C address 30 hex		
ELEC_TEST [3]	0	1 = electrical test on 0 = off
OPTIC_TEST [3]	1	1 = optic test on 0 = off
DARK_TEST [3]	2	1 = dark test on 0 = off
PREAMP_RANGE_HI [3]	3	1 = select high preamp range 0 = select low range
Internal outputs, U8, J108, pins 1–8 = bits 0–7, default I/O address 322 hex		
ELEC_TEST	0	1 = electrical test on 0 = off
OPTIC_TEST	1	1 = optic test on 0 = off
PREAMP_RANGE_HI	2	1 = select high preamp range 0 = select low range
	3–5	Spare
I2C_RESET	6	1 = reset I^{2}C peripherals 0 = normal
I2C_DRV_RST	7	0 = hardware reset 8584 chip 1 = normal
Control inputs, U11, J1004, pins 1–6 = bits 0–5, default I/O address 321 hex		
EXT_ZERO_CAL	0	0 = go into zero calibration 1 = exit zero calibration
EXT_SPAN_CAL	1	0 = go into span calibration 1 = exit span calibration
EXT_LOW_SPAN [2, 6]	2	0 = go into low span calibration 1 = exit low span calibration
EXT_BKGND_CAL [4]	3	0 = go into background calibration 1 = exit background calibration
	4–5	Spare
	6–7	Always 1
Control inputs, U14, J1006, pins 1–6 = bits 0–5, default I/O address 325 hex		
	0–5	Spare
	6–7	Always 1

SIGNAL NAME	BIT OR CHANNEL NUMBER	DESCRIPTION
Control outputs, U17, J1008, pins 1–8 = bits 0–7, default I/O address 321 hex		
	0–7	Spare
Control outputs, U21, J1008, pins 9–12 = bits 0–3, default I/O address 325 hex		
	0–3	Spare
Alarm outputs, U21, J1009, pins 1–12 = bits 4–7, default I/O address 325 hex		
ST_SYSTEM_OK2, MB_RELAY_36 [9]	4	1 = system OK
		0 = any alarm condition or in diagnostics mode
		Controlled by MODBUS coil register
ST_CONC_ALARM_1 [12], MB_RELAY_37 [9]	5	1 = conc. limit 1 exceeded
		0 = conc. OK
		Controlled by MODBUS coil register
ST_CONC_ALARM_2 [12], MB_RELAY_38 [9]	6	1 = conc. limit 2 exceeded
		0 = conc. OK
		Controlled by MODBUS coil register
ST_HIGH_RANGE2 [13], MB_RELAY_39 [9]	7	1 = high auto-range in use (mirrors *ST_HIGH_RANGE* status output)
		0 = low auto-range
		Controlled by MODBUS coil register
A status outputs, U24, J1017, pins 1–8 = bits 0–7, default I/O address 323 hex		
ST_SYSTEM_OK	0	0 = system OK
		1 = any alarm condition
ST_CONC_VALID	1	0 = conc. valid
		1 = warnings or other conditions that affect validity of concentration
ST_HIGH_RANGE	2	0 = high auto-range in use
		1 = low auto-range
ST_ZERO_CAL	3	0 = in zero calibration
		1 = not in zero
ST_SPAN_CAL	4	0 = in span calibration
		1 = not in span
ST_DIAG_MODE	5	0 = in diagnostic mode
		1 = not in diagnostic mode
ST_LOW_SPAN_CAL [2, 6]	6	0 = in low span calibration
		1 = not in low span
ST_BKGND_CAL [4]	7	0 = in background calibration
		1 = not in background calibration

SIGNAL NAME	BIT OR CHANNEL NUMBER	DESCRIPTION
B status outputs, U27, J1018, pins 1–8 = bits 0–7, default I/O address 324 hex		
ST_LAMP_ALARM	0	0 = lamp intensity low
		1 = lamp intensity OK
ST_DARK_CAL_ALARM	1	0 = dark cal. warning
		1 = dark cal. OK
ST_FLOW_ALARM	2	0 = any flow alarm
		1 = all flows OK
ST_PRESS_ALARM	3	0 = any pressure alarm
		1 = all pressures OK
ST_TEMP_ALARM	4	0 = any temperature alarm
		1 = all temperatures OK
ST_HVPS_ALARM	5	0 = HVPS alarm
		1 = HVPS OK
ST_CO2_CAL [11]	6	0 = in CO_2 calibration
		1 = not in CO_2 calibration
ST_O2_CAL [10]	7	0 = in O_2 calibration
		1 = not in O_2 calibration
Front panel I²C keyboard, default I²C address 4E hex		
MAINT_MODE	5 (input)	0 = maintenance mode
		1 = normal mode
LANG2_SELECT	6 (input)	0 = select second language
		1 = select first language (English)
SAMPLE_LED	8 (output)	0 = sample LED on
		1 = off
CAL_LED	9 (output)	0 = cal. LED on
		1 = off
FAULT_LED	10 (output)	0 = fault LED on
		1 = off
AUDIBLE_BEEPER	14 (output)	0 = beeper on (for diagnostic testing only)
		1 = off

SIGNAL NAME	BIT OR CHANNEL NUMBER	DESCRIPTION
Relay board digital output (PCF8575), default I^{2}C address 44 hex		
RELAY_WATCHDOG	0	Alternate between 0 and 1 at least every 5 seconds to keep relay board active
RCELL_HEATER	1	0 = reaction cell heater on 1 = off
	2–3	Spare
IZS_HEATER	4	0 = IZS heater on 1 = off
O2_CELL_HEATER [10]	5	0 = O$_2$ sensor cell heater on 1 = off
CAL_VALVE	6	0 = let cal. gas in 1 = let sample gas in
SPAN_VALVE	7	0 = let span gas in 1 = let zero gas in
LOW_SPAN_VALVE [2, 6]	8	0 = let low span gas in 1 = let sample gas in
CYLINDER_VALVE [7]	8	0 = open pressurized inlet valve 1 = close valve
ZERO_VALVE [2]	9	0 = let zero gas in 1 = let sample gas in
DARK_SHUTTER	10	0 = close dark shutter 1 = open
	11–15	Spare
AUX board analog inputs, default I^{2}C address 30 hex		
PMT_SIGNAL [3]	0 (register number)	PMT detector
UVLAMP_SIGNAL [3]	1	UV lamp intensity
NORM_PMT_SIGNAL [3]	2	Normalized PMT detector
PMT_TEMP [3]	3	PMT temperature
HVPS_VOLTAGE [3]	4	HV power supply output
PMT_DARK [3]	5	PMT reading during dark cycles
LAMP_DARK [3]	6	Lamp reading during dark cycles
AGND_DARK [3]	7	AGND reading during dark cycles
AGND_LIGHT [3]	8	AGND reading during light cycles
VREF_DARK [3]	9	VREF4096 reading during dark cycles
VREF_LIGHT [3]	10	VREF4096 reading during light cycles

SIGNAL NAME	BIT OR CHANNEL NUMBER	DESCRIPTION
Rear board primary MUX analog inputs		
PMT_SIGNAL	0	PMT detector
HVPS_VOLTAGE	1	HV power supply output
PMT_TEMP	2	PMT temperature
UVLAMP_SIGNAL	3	UV lamp intensity
	4	Temperature MUX
PHOTO_ABS [8]	5	Pre-amplified UV lamp intensity
O2_SENSOR [10]	6	O_2 concentration sensor
SAMPLE_PRESSURE	7	Sample pressure
TEST_INPUT_8	8	Diagnostic test input
REF_4096_MV	9	4.096V reference from MAX6241
SAMPLE_FLOW	10	Sample flow rate
VACUUM_PRESSURE [2]	10	Vacuum pressure
CO2_SENSOR [11]	11	CO_2 concentration sensor
	12–13	Spare (thermocouple input?)
	14	DAC MUX
REF_GND	15	Ground reference
Rear board temperature MUX analog inputs		
BOX_TEMP	0	Internal box temperature
RCELL_TEMP	1	Reaction cell temperature
IZS_TEMP	2	IZS temperature
	3	Spare
O2_CELL_TEMP [10]	4	O_2 sensor cell temperature
TEMP_INPUT_5	5	Diagnostic temperature input
TEMP_INPUT_6	6	Diagnostic temperature input
	7	Spare
Rear board DAC MUX analog inputs		
DAC_CHAN_1	0	DAC channel 0 loopback
DAC_CHAN_2	1	DAC channel 1 loopback
DAC_CHAN_3	2	DAC channel 2 loopback
DAC_CHAN_4	3	DAC channel 3 loopback
Rear board analog outputs		
CONC_OUT_1, DATA_OUT_1	0	Concentration output #1 (SO_2, range #1), Data output #1
CONC_OUT_2, DATA_OUT_2	1	Concentration output #2 (SO_2, range #2), Data output #2
CONC_OUT_3 [10,] DATA_OUT_3	2	Concentration output #3 (CO_2 or O_2), Data output #3
TEST_OUTPUT, DATA_OUT_4	3	Test measurement output, Data output #4

SIGNAL NAME	BIT OR CHANNEL NUMBER	DESCRIPTION
I^{2}C analog output (AD5321), default I^{2}C address 18 hex		
LAMP_POWER [5]	0	Lamp power (0–5V)

[1]   Optional.

[2]   T100H/M100EH.

[3]   T100U/M100EU.

[4]   Background concentration compensation option (6400E/6400EH).

[5]   Engineering firmware only.

[6]   Low span option.

[7]   Pressurized IZS option.

[8]   T100/M100E.

[9]   MODBUS option.

[10]   O$_2$ option.

[11]   CO$_2$ option.

[12]   Concentration alarm option.

[13]   High auto range relay option

APPENDIX A-5: DAS Functions

Table A-5: DAS Trigger Events, Software Version G.4

NAME	DESCRIPTION
ATIMER	Automatic timer expired
EXITZR	Exit zero calibration mode
EXITLS [2, 3]	Exit low span calibration mode
EXITHS	Exit high span calibration mode
EXITMP	Exit multi-point calibration mode
EXITBK [5]	Exit background calibration mode
EXITO2 [10]	Exit O_2 calibration mode
SLPCHG	Slope and offset recalculated
CO2SLC [11]	CO_2 slope and offset recalculated
O2SLPC [10]	O_2 slope and offset recalculated
EXITDG	Exit diagnostic mode
PMTDTW	PMT detector warning
UVLMPW	UV lamp warning
DRKCLW	Dark calibration warning
CONCW1 [4]	Concentration limit 1 exceeded
CONCW2 [4]	Concentration limit 2 exceeded
RCTMPW	Reaction cell temperature warning
O2TMPW [10]	O_2 sensor cell temperature warning
IZTMPW [1]	IZS temperature warning
PTEMPW	PMT temperature warning
SFLOWW	Sample flow warning
SPRESW	Sample pressure warning
VPRESW [2]	Vacuum pressure warning
BTEMPW	Box temperature warning
HVPSW	High voltage power supply warning

[1] T100/M100E.

[2] T100H/M100EH.

[3] Low span option.

[4] Concentration alarm option.

[5] Background concentration compensation option (6400E/6400EH).

[10] O_2 option.

[11] CO_2 option.

Table A-6: DAS Parameters

NAME	DESCRIPTION	UNITS
PMTDET	PMT detector reading	mV
PHABS [1]	Pre-amplified UV lamp intensity reading	mV
UVDET	UV lamp intensity reading	mV
LAMPR	UV lamp ratio of calibrated intensity	%
DRKPMT	PMT electrical offset	mV
DARKUV	UV lamp electrical offset	mV
SLOPE1	SO_2 slope for range #1	—
SLOPE2	SO_2 slope for range #2	—
OFSET1	SO_2 offset for range #1	mV
OFSET2	SO_2 offset for range #2	mV
CO2SLP [11]	CO_2 slope	—
CO2OFS [11]	CO_2 offset	%
O2SLPE [10]	O_2 slope	—
O2OFST [10]	O_2 offset	%
ZSCNC1	SO_2 concentration for range #1 during zero/span calibration, just before computing new slope and offset	PPB, PPM [2]
ZSCNC2	SO_2 concentration for range #2 during zero/span calibration, just before computing new slope and offset	PPB
CO2ZSC [11]	CO_2 concentration during zero/span calibration, just before computing new slope and offset	%
O2ZSCN [10]	O_2 concentration during zero/span calibration, just before computing new slope and offset	%
CONC1	SO_2 concentration for range #1	PPB
CONC2	SO_2 concentration for range #2	PPB
CNCBK1 [4]	SO_2 concentration plus background concentration for range #1	PPB
CNCBK2 [4]	SO_2 concentration plus background concentration for range #2	PPB
BKGND1 [4]	Background concentration for range #1	PPB
BKGND2 [4]	Background concentration for range #2	PPB
SO2CR1 [12]	SO_2 concentration for range #1, with O_2 correction	PPB
SO2CR2 [12]	SO_2 concentration for range #2, with O_2 correction	PPB
CO2CNC [11]	CO_2 concentration	%
O2CONC [10]	O_2 concentration	%
STABIL	Concentration stability #1	PPB
STABL2 [3]	Concentration stability #2	PPB
STABUV [3]	UV lamp stability	mV
STRLGT	Stray light reading	PPB
RCTEMP	Reaction cell temperature	°C
O2TEMP [10]	O_2 sensor cell temperature	°C
IZSTMP [1]	IZS temperature	°C
PMTTMP	PMT temperature	°C
SMPFLW	Sample flow	cc/m
SMPPRS	Sample pressure	"Hg

NAME	DESCRIPTION	UNITS
VACUUM [2]	Vacuum pressure	"Hg
BOXTMP	Internal box temperature	°C
HVPS	High voltage power supply output	Volts
TEST8	Diagnostic test input (TEST_INPUT_8)	mV
TEMP5	Diagnostic temperature input (TEMP_INPUT_5)	°C
TEMP6	Diagnostic temperature input (TEMP_INPUT_6)	°C
REFGND	Ground reference (REF_GND)	mV
RF4096	4096 mV reference (REF_4096_MV)	mV
XIN1[13]	Channel 1 Analog In	
XIN1SLPE[13]	Channel 1 Analog In Slope	
XIN1OFST[13]	Channel 1 Analog In Offset	
XIN2[13]	Channel 2 Analog In	
XIN2SLPE[13]	Channel 2 Analog In Slope	
XIN2OFST[13]	Channel 2 Analog In Offset	
XIN3[13]	Channel 3 Analog In	
XIN3SLPE[13]	Channel 3 Analog In Slope	
XIN3OFST[13]	Channel 3 Analog In Offset	
XIN4[13]	Channel 4 Analog In	
XIN4SLPE[13]	Channel 4 Analog In Slope	
XIN4OFST[13]	Channel 4 Analog In Offset	
XIN5[13]	Channel 5 Analog In	
XIN5SLPE[13]	Channel 5 Analog In Slope	
XIN5OFST[13]	Channel 5 Analog In Offset	
XIN6[13]	Channel 6 Analog In	
XIN6SLPE[13]	Channel 6 Analog In Slope	
XIN6OFST[13]	Channel 6 Analog In Offset	
XIN7[13]	Channel 7 Analog In	
XIN7SLPE[13]	Channel 7 Analog In Slope	
XIN7OFST[13]	Channel 7 Analog In Offset	
XIN8[13]	Channel 8 Analog In	
XIN8SLPE[13]	Channel 8 Analog In Slope	
XIN8OFST[13]	Channel 8 Analog In Offset	
AGNDDK [3]	AGND reading during dark cycles	mV
AGNDLT [3]	AGND reading during light cycles	mV
RF4VDK [3]	VREF4096 reading during dark cycles	mV
RF4VLT [3]	VREF4096 reading during light cycles	mV

NAME	DESCRIPTION	UNITS
[1]	T100/M100E.	
[2]	T100H/M100EH.	
[3]	T100U/M100EU.	
[4]	Background concentration compensation option (6400E/6400EH).	
[10]	O_2 option.	
[11]	CO_2 option.	
[12]	SO_2 with O_2 correction option.	
[13]	Analog In option, T-Series only.	

APPENDIX A-6: Terminal Command Designators

Table A-7: Terminal Command Designators

COMMAND	ADDITIONAL COMMAND SYNTAX	DESCRIPTION
? [ID]		Display help screen and this list of commands
LOGON [ID]	password	Establish connection to instrument
LOGOFF [ID]		Terminate connection to instrument
T [ID]	SET ALL|name|hexmask	Display test(s)
	LIST [ALL|name|hexmask] [NAMES|HEX]	Print test(s) to screen
	name	Print single test
	CLEAR ALL|name|hexmask	Disable test(s)
W [ID]	SET ALL|name|hexmask	Display warning(s)
	LIST [ALL|name|hexmask] [NAMES|HEX]	Print warning(s)
	name	Clear single warning
	CLEAR ALL|name|hexmask	Clear warning(s)
C [ID]	ZERO|LOWSPAN|SPAN [1|2]	Enter calibration mode
	ASEQ number	Execute automatic sequence
	COMPUTE ZERO|SPAN	Compute new slope/offset
	EXIT	Exit calibration mode
	ABORT	Abort calibration sequence
D [ID]	LIST	Print all I/O signals
	name[=value]	Examine or set I/O signal
	LIST NAMES	Print names of all diagnostic tests
	ENTER name	Execute diagnostic test
	EXIT	Exit diagnostic test
	RESET [DATA] [CONFIG] [exitcode]	Reset instrument
	PRINT ["name"] [SCRIPT]	Print DAS configuration
	RECORDS ["name"]	Print number of DAS records
	REPORT ["name"] [RECORDS=number] [FROM=<start date>][TO=<end date>][VERBOSE|COMPACT|HEX] (Print DAS records)(date format: MM/DD/YYYY(or YY) [HH:MM:SS]	Print DAS records
	CANCEL	Halt printing DAS records
V [ID]	LIST	Print setup variables
	name[=value [warn_low [warn_high]]]	Modify variable
	name="value"	Modify enumerated variable
	CONFIG	Print instrument configuration
	MAINT ON|OFF	Enter/exit maintenance mode
	MODE	Print current instrument mode
	DASBEGIN [<data channel definitions>] DASEND	Upload DAS configuration
	CHANNELBEGIN propertylist CHANNELEND	Upload single DAS channel
	CHANNELDELETE ["name"]	Delete DAS channels

The command syntax follows the command type, separated by a space character. Strings in [brackets] are optional designators. The following key assignments also apply.

TERMINAL KEY ASSIGNMENTS	
ESC	Abort line
CR (ENTER)	Execute command
Ctrl-C	Switch to computer mode
COMPUTER MODE KEY ASSIGNMENTS	
LF (line feed)	Execute command
Ctrl-T	Switch to terminal mode

APPENDIX A-7: MODBUS Register Map

MODBUS Register Address (dec., 0-based)	Description	Units
MODBUS Floating Point Input Registers (32-bit IEEE 754 format; read in high-word, low-word order; read-only)	
0	PMT detector reading	mV
2	UV lamp intensity reading	mV
4	UV lamp ratio of calibrated intensity	%
6	PMT electrical offset	mV
8	UV lamp electrical offset	mV
10	SO_2 slope for range #1	—
12	SO_2 slope for range #2	—
14	SO_2 offset for range #1	mV
16	SO_2 offset for range #2	mV
18	SO_2 concentration for range #1 during zero/span calibration, just before computing new slope and offset	PPB, PPM [2]
20	SO_2 concentration for range #2 during zero/span calibration, just before computing new slope and offset	PPB
22	SO_2 concentration for range #1	PPB
24	SO_2 concentration for range #2	PPB
26	Concentration stability	PPB
28	Stray light reading	PPB
30	Reaction cell temperature	°C
32	PMT temperature	°C
34	Sample pressure	"Hg
36	Internal box temperature	°C
38	High voltage power supply output	Volts
40	Diagnostic test input (TEST_INPUT_8)	mV
42	Diagnostic temperature input (TEMP_INPUT_5)	°C
44	Diagnostic temperature input (TEMP_INPUT_6)	°C
46	Ground reference (REF_GND)	mV
48	4096 mV reference (REF_4096_MV)	mV
50	Sample flow	cc/m
52 [1]	IZS temperature	°C
54 [2]	Vacuum pressure	"Hg
56 [1]	Pre-amplified UV lamp intensity reading	mV
100 [10]	O_2 concentration	%
102 [10]	O_2 concentration during zero/span calibration, just before computing new slope and offset	%
104 [10]	O_2 slope	—
106 [10]	O_2 offset	%
108 [10]	O_2 sensor cell temperature	°C

MODBUS Register Address (dec., 0-based)	Description	Units
110 [12]	SO_2 concentration for range #1, with O_2 correction	PPB
112 [12]	SO_2 concentration for range #2, with O_2 correction	PPB
130 [14]	External analog input 1 value	Volts
132 [14]	External analog input 1 slope	eng unit /V
134 [14]	External analog input 1 offset	eng unit
136 [14]	External analog input 2 value	Volts
138 [14]	External analog input 2 slope	eng unit /V
140 [14]	External analog input 2 offset	eng unit
142 [14]	External analog input 3 value	Volts
144 [14]	External analog input 3 slope	eng unit /V
146 [14]	External analog input 3 offset	eng unit
148 [14]	External analog input 4 value	Volts
150 [14]	External analog input 4 slope	eng unit /V
152 [14]	External analog input 4 offset	eng unit
154 [14]	External analog input 5 value	Volts
156 [14]	External analog input 5 slope	eng unit /V
158 [14]	External analog input 5 offset	eng unit
160 [14]	External analog input 6 value	Volts
162 [14]	External analog input 6 slope	eng unit /V
164 [14]	External analog input 6 offset	eng unit
166 [14]	External analog input 7 value	Volts
168 [14]	External analog input 7 slope	eng unit /V
170 [14]	External analog input 7 offset	eng unit
172 [14]	External analog input 8 value	Volts
174 [14]	External analog input 8 slope	eng unit /V
176 [14]	External analog input 8 offset	eng unit
200 [11]	CO_2 concentration	%
202 [11]	CO_2 concentration during zero/span calibration, just before computing new slope and offset	%
204 [11]	CO_2 slope	—
206 [11]	CO_2 offset	%
MODBUS Floating Point Holding Registers **(32-bit IEEE 754 format; read/write in high-word, low-word order; read/write)**		
0	Maps to *SO2_SPAN1* variable; target conc. for range #1	Conc. units
2	Maps to *SO2_SPAN2* variable; target conc. for range #2	Conc. units
100 [10]	Maps to *O2_TARG_SPAN_CONC* variable	%
200 [11]	Maps to *CO2_TARG_SPAN_CONC* variable	%

MODBUS Register Address (dec., 0-based)	Description	Units
MODBUS Discrete Input Registers (single-bit; read-only)	
0	PMT detector warning	
1	UV detector warning	
2	Dark calibration warning	
3	Box temperature warning	
4	PMT temperature warning	
5	Reaction cell temperature warning	
6	Sample pressure warning	
7	HVPS warning	
8	System reset warning	
9	Rear board communication warning	
10	Relay board communication warning	
11	Front panel communication warning	
12	Analog calibration warning	
13	Dynamic zero warning	
14	Dynamic span warning	
15	Invalid concentration	
16	In zero calibration mode	
17	In span calibration mode	
18	In multi-point calibration mode	
19	System is OK (same meaning as *SYSTEM_OK* I/O signal)	
20	Sample flow warning	
21 [1]	IZS temperature warning	
22 [2]	In low span calibration mode	
23 [2]	Vacuum pressure warning	
24 [3]	SO_2 concentration alarm limit #1 exceeded	
25 [3]	SO_2 concentration alarm limit #2 exceeded	
26	In Hessen manual mode	
100 [10]	In O_2 calibration mode	
101 [10]	O_2 cell temperature warning	
102 [10+3]	O_2 concentration alarm limit #1 exceeded	
103 [10+3]	O_2 concentration alarm limit #2 exceeded	
200 [11]	In CO_2 calibration mode	
201 [11+3]	CO_2 concentration alarm limit #1 exceeded	
202 [11+3]	CO_2 concentration alarm limit #2 exceeded	

MODBUS Register Address (dec., 0-based)	Description	Units
MODBUS Coil Registers (single-bit; read/write)		
0	Maps to relay output signal 36 (*MB_RELAY_36* in signal I/O list)	
1	Maps to relay output signal 37 (*MB_RELAY_37* in signal I/O list)	
2	Maps to relay output signal 38 (*MB_RELAY_38* in signal I/O list)	
3	Maps to relay output signal 39 (*MB_RELAY_39* in signal I/O list)	
20 [13]	Triggers zero calibration of range #1 (on enters cal.; off exits cal.)	
21 [13]	Triggers span calibration of range #1 (on enters cal.; off exits cal.)	
22 [13]	Triggers zero calibration of range #2 (on enters cal.; off exits cal.)	
23 [13]	Triggers span calibration of range #2 (on enters cal.; off exits cal.)	

[1] M100E.

[2] M100EH.

[3] Concentration alarm option.

[10] O_2 option.

[11] CO_2 option.

[12] SO_2 with O_2 correction option.

[13] Set *DYN_ZERO* or *DYN_SPAN* variables to *ON* to enable calculating new slope or offset. Otherwise a calibration check is performed.

[14] External analog input option.

APPENDIX B - Spare Parts

Note	Use of replacement parts other than those supplied by API may result in non compliance with European standard EN 61010-1.

Note	Due to the dynamic nature of part numbers, please refer to the Website or call Sales for more recent updates to the Spare Parts list.

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Part Number	Description
000940100	ORIFICE, 3 MIL, IZS
000940400	CD, ORIFICE, .004 BLUE
000940800	ORIFICE, 012 MIL, RXCELL
002690000	LENS, UV
002700000	LENS, PMT
002720000	FILTER, PMT OPTICAL, 330 NM
003290000	ASSY, THERMISTOR
005960000	AKIT, EXP, 6LBS ACT CHARCOAL (2 BT=1)
009690000	AKIT, TFE FLTR ELEM (FL6 100=1) 47mm
009690100	AKIT, TFE FLTR ELEM (FL6, 30=1) 47mm
011630000	HVPS INSULATOR GASKET (KB)
012720100	OPTION, NOx OPTICAL FILTER *
013140000	ASSY, COOLER FAN (NOX/SOX)
013210000	ASSY, VACUUM MANIFOLD
013390000	ASSY, KICKER
013400000	CD, PMT, SO2, (KB)
013420000	ASSY, ROTARY SOLENOID
013570000	ASSY, THERMISTOR (COOLER)
014080100	ASSY, HVPS, SOX/NOX
014400100	OPTION, ZERO AIR SCRUBBER
014750000	AKIT, EXP KIT, IZS
016290000	WINDOW, SAMPLE FILTER, 47MM (KB)
016300700	ASSY, SAMPLE FILTER, 47MM, ANG BKT
037860000	ORING, TFE RETAINER, SAMPLE FILTER
040010000	ASSY, FAN REAR PANEL
040030100	PCA, FLOW/PRESSURE
041620100	ASSY, SO2 SENSOR (KB)
041800400	PCA, PMT PREAMP, VR
041920000	ASSY, THERMISTOR
042410200	ASSY, PUMP, INT, E SERIES
043420000	ASSY, HEATER/THERM, O2 SEN
043570000	AKIT, EXPENDABLES
045230200	PCA, RELAY CARD W/RELAYS, E SERIES, S/N'S >455
046250000	ASSY, RXCELL HEATER/FUSE
046260000	ASSY, THERMISTOR, RXCELL (KB)
048830000	AKIT, EXP KIT, EXHAUST CLNSR, SILCA GEL
049310100	PCA, TEC CONTROL, E SERIES
050510200	PUMP, INT, 115/240V * (KB)
050610100	CONFIGURATION PLUGS, 115V/60Hz
050610200	CONFIGURATION PLUGS, 115V/50Hz
050610300	CONFIGURATION PLUGS, 220-240V/50Hz
050610400	CONFIGURATION PLUGS, 220-240V/60Hz
050630100	PCA, M100E UV REF DETECTOR
051990000	ASSY, SCRUBBER, INLINE EXHAUST, DISPOS

Part Number	Description
052660000	ASSY, HEATER/THERMISTOR (IZS)
055100200	ASSY, OPTION, PUMP, 240V *
055560000	ASSY, VALVE, VA59 W/DIODE, 5" LEADS
055560100	ASSY, VALVE, VA59 W/DIODE, 9" LEADS
058021100	PCA,E-SERIES MOTHERBD, GEN 5 ICOP (ACCEPTS ACROSSER OR ICOP CPU)
061930000	PCA, UV LAMP DRIVER, GEN-2 43mA *
062420200	PCA, SER INTRFACE, ICOP CPU, E- (OPTION) (USE WITH ICOP CPU 062870000)
066970000	PCA, INTRF. LCD TOUCH SCRN, F/P
067240000	CPU, PC-104, VSX-6154E, ICOP *
067300000	PCA, AUX-I/O BD, ETHERNET, ANALOG & USB
067300100	PCA, AUX-I/O BOARD, ETHERNET
067300200	PCA, AUX-I/O BOARD, ETHERNET & USB
067900000	LCD MODULE, W/TOUCHSCREEN
068070000	MANUAL, OPERATORS, T100
068220100	DOM, w/SOFTWARE, T100 *
068810000	PCA, LVDS TRANSMITTER BOARD
069500000	PCA, SERIAL & VIDEO INTERFACE BOARD
072150000	ASSY. TOUCHSCREEN CONTROL MODULE
CN0000073	POWER ENTRY, 120/60 (KB)
CN0000458	CONNECTOR, REAR PANEL, 12 PIN
CN0000520	CONNECTOR, REAR PANEL, 10 PIN
FL0000001	FILTER, FLOW CONTROL
FL0000003	FILTER, DFU (KB)
FM0000004	FLOWMETER (KB)
HW0000005	FOOT, CHASSIS
HW0000020	SPRING, FLOW CONTROL
HW0000030	ISOLATOR
HW0000031	FERRULE, SHOCKMOUNT
HW0000036	TFE TAPE, 1/4" (48 FT/ROLL)
HW0000101	ISOLATOR
HW0000453	SUPPORT, CIRCUIT BD, 3/16" ICOP
HW0000685	LATCH, MAGNETIC, FRONT PANEL
KIT000093	AKIT, REPLCMNT(3187)214NM FLTR (BF)
KIT000095	AKIT, REPLACEMENT COOLER
KIT000207	KIT, RELAY RETROFIT
KIT000219	AKIT, 4-20MA CURRENT OUTPUT
KIT000236	KIT, UV LAMP, w/ADAPTER (BIR)
KIT000253	ASSY & TEST, SPARE PS37
KIT000254	ASSY & TEST, SPARE PS38
OP0000030	OXYGEN TRANSDUCER, PARAMAGNETIC
OP0000031	WINDOW, QUARTZ, REF DETECTOR
OR0000001	ORING, FLOW CONTROL/IZS
OR0000004	ORING, OPTIC/CELL, CELL/TRAP
OR0000006	ORING, CELL/PMT
OR0000007	ORING, PMT/BARREL/CELL
OR0000015	ORING, PMT FILTER

Part Number	Description
OR0000016	ORING, UV LENS
OR0000025	ORING, ZERO AIR SCRUBBER
OR0000027	ORING, COLD BLOCK/PMT HOUSING & HEATSINK
OR0000039	ORING, QUARTZ WINDOW/REF DETECTOR
OR0000046	ORING, PERMEATION OVEN
OR0000083	ORING, PMT SIGNAL & OPTIC LED
OR0000084	ORING, UV FILTER
OR0000094	ORING, SAMPLE FILTER
PU0000022	KIT, PUMP REBUILD
RL0000015	RELAY, DPDT, (KB)
SW0000006	SWITCH, THERMAL, 60 C
SW0000025	SWITCH, POWER, CIRC BREAK, VDE/CE *
SW0000059	PRESSURE SENSOR, 0-15 PSIA, ALL SEN
WR0000008	POWER CORD, 10A(KB)

IZS, AKIT, EXPENDABLES
T100/M100E
(Reference 01475A)

Part Number	Description
014750000	AKIT, EXP KIT, M100A/M100E, IZS

Part Number	Description
005960000	AKIT, EXPEND, 6LBS ACT CHARCOAL
006900000	RETAINER PAD CHARCOAL, SMALL, 1-3/4"
FL0000001	FILTER, SS
FL0000003	FILTER, DFU (KB)
HW0000020	SPRING
OR0000001	ORING, 2-006VT
OR0000046	ORING, 2-019V

CUSTOMER: _____ PHONE: _____

CONTACT NAME: _____ FAX NO. _____

SITE ADDRESS: _____

MODEL SERIAL NO.: _____ FIRMWARE REVISION: _____

1. ARE THERE ANY FAILURE MESSAGES? _____

_____

_____

2. PLEASE COMPLETE THE FOLLOWING TABLE: (**NOTE:** *DEPENDING ON OPTIONS INSTALLED, NOT ALL TEST PARAMETERS BELOW WILL BE AVAILABLE IN YOUR INSTRUMENT*)

*IF OPTION IS INSTALLED

Parameter	Recorded Value	Acceptable Value
RANGE	PPB/PPM	50 PPB to 20 PPM
STABIL	PPB	≤1 PPB WITH ZERO AIR
SAMP PRESS	IN-HG-A	~ 2" < AMBIENT
SAMPLE FLOW	cm³/MIN	650 ± 10%
PMT SIGNAL WITH ZERO AIR	mV	-20 TO 150 mV
PMT SIGNAL AT SPAN GAS CONC	mV PPB/PPM	0-5000 mV 0-20000 PPB
NORM PMT AT SPAN GAS CONC	mV PPB/PPM	0-5000 mV 0-20000 PPB
UV LAMP	mV	1000 TO 4800 mV
LAMP RATIO	mV	30 TO 120%
STR. LGT	PPB	≤ 100 PPB/ ZERO AIR
DARK PMT	mV	-50 TO 200 mV
DARK LAMP	mV	-50 TO 200 mV
SLOPE		1.0 ± 0.3
OFFSET	mV	< 250 mV
HVPS	V	≈ 400 – 900
RCELL TEMP	℃	50℃ ± 1
BOX TEMP	℃	AMBIENT + ~ 5
PMT TEMP	℃	7℃ ± 2° CONSTANT
IZS TEMP*	℃	50℃ ± 1
ETEST	mV	2000 mV ± 1000
OTEST	mV	2000 mV ± 1000
Values are in the Signal I/O		
REF_4096_MV	mV	4096mv±2mv and Must be Stable
REF_GND	mV	0± 0.5 and Must be Stable

3. WHAT IS THE SAMPLE FLOW & SAMPLE PRESSURE W/SAMPLE INLET ON REAR OF MACHINE CAPPED?

SAMPLE FLOW - _____CC   **SAMPLE PRESS** - _____IN-HG-A

TELEDYNE API CUSTOMER SERVICE
Email: SDA_techsupport@teledyne.com
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4.   WHAT ARE THE FAILURE SYMPTOMS? _____

_____

_____

_____

_____

_____

_____

_____

_____

_____

5.   IF POSSIBLE, PLEASE INCLUDE A PORTION OF A STRIP CHART PERTAINING TO THE PROBLEM. CIRCLE
      PERTINENT DATA.

THANK YOU FOR PROVIDING THIS INFORMATION. YOUR ASSISTANCE ENABLES TELEDYNE API TO RESPOND
FASTER TO THE PROBLEM THAT YOU ARE ENCOUNTERING.

TELEDYNE API CUSTOMER SERVICE
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PHONE: (858) 657-9800   TOLL FREE: (800) 324-5190   FAX: (858) 657-9816

APPENDIX D – Wire List and Electronic Schematics

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Interconnect List, T100

(Reference 0690801A)

Revision	Description					Checked	Date	DCN
A	Initial Release					KV	9/3/10	5833
			FROM			**TO**		
Cable PN	Signal	Assembly	PN	J/P	Pin	Assembly	PN	J/P	Pin
---	---	---	---	---	---	---	---	---	---
0364901	**CBL ASSY, AC POWER**								
	AC Line	Power Entry	CN0000073		L	Power Switch	SW0000025		L
	AC Neutral	Power Entry	CN0000073		N	Power Switch	SW0000025		N
	Power Grnd	Power Entry	CN0000073			Shield			
	Power Grnd	Power Entry	CN0000073			Chassis			
	AC Line Switched	Power Switch	SW0000025		L	PS2 (+12)	068020000	SK2	1
	AC Neu Switched	Power Switch	SW0000025		N	PS2 (+12)	068020000	SK2	3
	Power Grnd	Power Entry	CN0000073			PS2 (+12)	068020000	SK2	2
	AC Line Switched	Power Switch	SW0000051		L	PS1 (+5, ±15)	068010000	SK2	1
	AC Neu Switched	Power Switch	SW0000025		N	PS1 (+5, ±15)	068010000	SK2	3
	Power Grnd	Power Entry	CN0000073			PS1 (+5, ±15)	068010000	SK2	2
	AC Line Switched	Power Switch	SW0000025		L	Relay PCA	045230100	J1	1
	AC Neu Switched	Power Switch	SW0000025		N	Relay PCA	045230100	J1	3
	Power Grnd	Power Entry	CN0000073			Relay PCA	045230100	J1	2
03829	**CBL ASSY, DC POWER TO MOTHERBOARD**								
	DGND	Relay PCA	045230100	J7	1	Motherboard	058021100	J15	1
	+5V	Relay PCA	045230100	J7	2	Motherboard	058021100	J15	2
	AGND	Relay PCA	045230100	J7	3	Motherboard	058021100	J15	3
	+15V	Relay PCA	045230100	J7	4	Motherboard	058021100	J15	4
	AGND	Relay PCA	045230100	J7	5	Motherboard	058021100	J15	5
	-15V	Relay PCA	045230100	J7	6	Motherboard	058021100	J15	6
	+12V RET	Relay PCA	045230100	J7	7	Motherboard	058021100	J15	7
	+12V	Relay PCA	045230100	J7	8	Motherboard	058021100	J15	8
	Chassis Gnd	Relay PCA	045230100	J7	10	Motherboard	058021100	J15	9
04023	**CBL, I2C, RELAY BOARD TO MOTHERBOARD**								
	I2C Serial Clock	Motherboard	058021100	P107	3	Relay PCA	045230100	P3	1
	I2C Serial Data	Motherboard	058021100	P107	5	Relay PCA	045230100	P3	2
	I2C Reset	Motherboard	058021100	P107	2	Relay PCA	045230100	P3	4
	I2C Shield	Motherboard	058021100	P107	6	Relay PCA	045230100	P3	5
0402602	**CBL, IZS HTR/TH, RXCELL & OB TH**								
	RTHA	Motherboard	058021100	P27	7	RX Cell Thermistor	046260000		2
	RTHB	Motherboard	058021100	P27	14	RX Cell Thermistor	046260000		1
	IZTA	Motherboard	058021100	P27	6	IZS Therm/Htr	052660000		2
	IZTB	Motherboard	058021100	P27	13	IZS Therm/Htr	052660000		3
	IZS-L	Relay PCA	045230100	P18	1	IZS Therm/Htr	052660000		4
	IZS-N	Relay PCA	045230100	P18	2	IZS Therm/Htr	052660000		1
	GND	Relay PCA	045230100	P18	11	Shield			
	O2-L	Relay PCA	045230100	P18	6	O2 Sensor Therm/Htr	043420000		4
	O2-N	Relay PCA	045230100	P18	7	O2 Sensor Therm/Htr	043420000		2
	TS3	Relay PCA	045230100	P18	3	Relay PCA	045230100	P18	4
	TS4	Relay PCA	045230100	P18	8	Relay PCA	045230100	P18	9
	N/C	Relay PCA	045230100	P18	12	Shield			
	O2TA	Motherboard	058021100	P27	4	O2 Sensor Therm/Htr	043420000		3
	O2TB	Motherboard	058021100	P27	11	O2 Sensor Therm/Htr	043420000		1
0402701	**CBL, RX CELL HEATERS**								
	RH1B	Relay PCA	045230100	P2	1	RX Cell Heaters	046250000		4
	RH2B	Relay PCA	045230100	P2	1	RX Cell Heaters	046250000		6
	RH1A	Relay PCA	045230100	P2	2	RX Cell Heaters	046250000		3
	RTS1	Relay PCA	045230100	P2	3	RX Cell Heaters	046250000		1
	RTS2	Relay PCA	045230100	P2	4	RX Cell Heaters	046250000		2
	RH2A	Relay PCA	045230100	P2	5	RX Cell Heaters	046250000		5
		Relay PCA	045230100	P2	13	Relay PCA	045230100	P2	14
		Relay PCA	045230100	P2	8	Relay PCA	045230100	P2	9
04105	**CBL, KEYBD TO MTHBRD**								
	Kbd Interupt	LCD Interface PCA	066970000	J1	7	Motherboard	058021100	J106	1
	DGND	LCD Interface PCA	066970000	J1	2	Motherboard	058021100	J106	8
	SDA	LCD Interface PCA	066970000	J1	5	Motherboard	058021100	J106	2
	SCL	LCD Interface PCA	066970000	J1	6	Motherboard	058021100	J106	6
	Shld	LCD Interface PCA	066970000	J1	10	Motherboard	058021100	J106	5

Interconnect List, T100
(Reference 0690801A)

Cable PN	Signal	FROM Assembly	PN	J/P	Pin	TO Assembly	PN	J/P	Pin
04176	**CBL, DC POWER TO RELAY BOARD**								
	DGND	Relay PCA	045230100	P8	1	Power Supply Triple	068010000	J1	3
	+5V	Relay PCA	045230100	P8	2	Power Supply Triple	068010000	J1	1
	+15V	Relay PCA	045230100	P8	4	Power Supply Triple	068010000	J1	6
	AGND	Relay PCA	045230100	P8	5	Power Supply Triple	068010000	J1	4
	-15V	Relay PCA	045230100	P8	6	Power Supply Triple	068010000	J1	5
	+12V RET	Relay PCA	045230100	P8	7	Power Supply Single	068020000	J1	3
	+12V	Relay PCA	045230100	P8	8	Power Supply Single	068020000	J1	1
04437	**CBL, PREAMPLIFIER TO TEC**								
	Preamp TEC drive VREF	Preamp PCA	041800400	J1	1	TEC PCA	049310100	J3	1
	Preamp TEC drive CTRL	Preamp PCA	041800400	J1	2	TEC PCA	049310100	J3	2
	Preamp TEC drive AGND	Preamp PCA	041800400	J1	3	TEC PCA	049310100	J3	3
0448501	**CBL, SHUTTER TO RELAY BOARD**								
	+12V RET	Shutter	013420000		1	Relay PCA	045230100	P6	1
	+12V	Shutter	013420000		2	Relay PCA	045230100	P6	2
04488	**CBL, MAIN HARNESS**								
	AGND	Relay PCA	045230100	P5	1	O2 Sensor	049210000	P1	5
	-V15	Relay PCA	045230100	P5	2	O2 Sensor	049210000	P1	6
		Motherboard	058021100	P109	10	O2 Sensor	049210000	P1	9
	O2 SIGNAL-	Motherboard	058021100	P109	7	O2 Sensor	049210000	P1	10
	O2 SIGNAL+	Motherboard	058021100	P109	1	Shield			
	PMT TEMP	Motherboard	058021100	P109	4	PMT Preamp PCA	041800400	P6	5
	HVPS	Motherboard	058021100	P109	5	PMT Preamp PCA	041800400	P6	6
	PMT SIGNAL+	Motherboard	058021100	P109	6	PMT Preamp PCA	041800400	P6	7
	AGND	Motherboard	058021100	P109	12	PMT Preamp PCA	041800400	P6	8
	AGND	Motherboard	058021100	P109	11	Shield			
	ETEST	Motherboard	058021100	P108	8	PMT Preamp PCA	041800400	P6	1
	OTEST	Motherboard	058021100	P108	16	PMT Preamp PCA	041800400	P6	2
	PHYSICAL RANGE	Motherboard	058021100	P108	7	PMT Preamp PCA	041800400	P6	4
	AGND	Motherboard	058021100	P109	9	UV Ref PCA	050630100	P1	4
	CH7	Motherboard	058021100	P109	3	UV Ref PCA	050630100	P1	1
	CH2	Motherboard	058021100	P109	2	UV Ref PCA	050630100	P1	5
	+15V	Relay PCA	045230100	P10	4	UV Ref PCA	050630100	P1	2
	-15V	Relay PCA	045230100	P10	6	UV Ref PCA	050630100	P1	3
	TEC +12V RET	Relay PCA	045230100	P10	7	TEC PCA	049310100		2
	TEC +12V	Relay PCA	045230100	P10	8	TEC PCA	049310100		1
	DISP RET	Relay PCA	045230100	P10	1	LCD Interface PCA	066970000	P14	8
	+5 DISP	Relay PCA	045230100	P10	2	LCD Interface PCA	066970000	P14	1
	EGND	Shield				LCD Interface PCA	066970000	P14	4
	SDA	Lamp Driver PCA	061930000	P1	4	LCD Interface PCA	066970000	P14	5
	SCL	Lamp Driver PCA	061930000	P1	3	LCD Interface PCA	066970000	P14	6
	+12V	Lamp Driver PCA	061930000	P1	1	Relay PCA	045230100	P9	8
	+12RET	Lamp Driver PCA	061930000	P1	2	Relay PCA	045230100	P9	7
	DGND	PMT Preamp PCA	041800400	P5	1	Relay PCA	045230100	P9	1
	VCC	PMT Preamp PCA	041800400	P5	2	Relay PCA	045230100	P9	2
	+15V	PMT Preamp PCA	041800400	P5	4	Relay PCA	045230100	P9	4
	-15V	PMT Preamp PCA	041800400	P5	6	Relay PCA	045230100	P9	6
	DGND	LCD Interface PCA	066970000	P14	2	Relay PCA	045230100	P11	1
	VCC	LCD Interface PCA	066970000	P14	3	Relay PCA	045230100	P11	2
	+12RET	Fan	040010000		1	Relay PCA	045230100	P11	7
	+12V	Fan	040010000		2	Relay PCA	045230100	P11	8
	AGND	Flow Module PCA	040030100	P1	3	Relay PCA	045230100	P11	3
	+15V	Flow Module PCA	040030100	P1	6	Relay PCA	045230100	P11	4
	PRESS SIGNAL 1	Flow Module PCA	040030100	P1	2	Motherboard	058021100	P110	6
	PRESS SIGNAL 2	Flow Module PCA	040030100	P1	4	Motherboard	058021100	P110	5
	FLOW SIGNAL 1	Flow Module PCA	040030100	P1	5	Motherboard	058021100	P110	4
	FLOW SIGNAL 2	Flow Module PCA	040030100	P1	1	Motherboard	058021100	P110	3
	SHIELD	Shield				Motherboard	058021100	P110	12
	SHIELD	Shield				Motherboard	058021100	P110	9
	TC SIGNAL 1	Relay PCA	045230100	P17	1	Motherboard	058021100	P110	2
	TC 1 SIGNAL DGND	Relay PCA	045230100	P17	2	Motherboard	058021100	P110	8
	TC SIGNAL 2	Relay PCA	045230100	P17	3	Motherboard	058021100	P110	1
	TC 2 SIGNAL DGND	Relay PCA	045230100	P17	4	Motherboard	058021100	P110	7

Interconnect List, T100

(Reference 0690801A)

Cable PN	Signal	FROM Assembly	FROM PN	FROM J/P	FROM Pin	TO Assembly	TO PN	TO J/P	TO Pin
04562	**CBL, Z/S IZS VALVES**								
	Sample Valve +12V	Relay PCA	045230100	P4	1	SMP/CAL	055560000		1
	Sample Valve +12V RET	Relay PCA	045230100	P4	2	SMP/CAL	055560000		2
	Zero/Span valve +12V	Relay PCA	045230100	P4	3	ZS/HI S	055560100		1
	Zero/Span valve +12V RE	Relay PCA	045230100	P4	4	ZS/HI S	055560100		2
	Low Span Valve +12V	Relay PCA	045230100	P4	5	Lo Span	055560100		1
	Low Span Valve +12V RE	Relay PCA	045230100	P4	6	Lo Span	055560100		2
	AutoZero Valve +12V	Relay PCA	045230100	P4	7	Zero	055560000		1
	AutoZero Valve +12V RE	Relay PCA	045230100	P4	8	Zero	055560000		2
04671	**CBL, MOTHERBOARD TO XMITTER BD (MULTIDROP OPTION**								
	GND	Motherboard	058021100	P12	2	Xmitter bd w/Multidrop	069500000	J4	2
	RX0	Motherboard	058021100	P12	14	Xmitter bd w/Multidrop	069500000	J4	14
	RTS0	Motherboard	058021100	P12	13	Xmitter bd w/Multidrop	069500000	J4	13
	TX0	Motherboard	058021100	P12	12	Xmitter bd w/Multidrop	069500000	J4	12
	CTS0	Motherboard	058021100	P12	11	Xmitter bd w/Multidrop	069500000	J4	11
	RS-GND0	Motherboard	058021100	P12	10	Xmitter bd w/Multidrop	069500000	J4	10
	RTS1	Motherboard	058021100	P12	8	Xmitter bd w/Multidrop	069500000	J4	8
	CTS1/485-	Motherboard	058021100	P12	6	Xmitter bd w/Multidrop	069500000	J4	6
	RX1	Motherboard	058021100	P12	9	Xmitter bd w/Multidrop	069500000	J4	9
	TX1/485+	Motherboard	058021100	P12	7	Xmitter bd w/Multidrop	069500000	J4	7
	RS-GND1	Motherboard	058021100	P12	5	Xmitter bd w/Multidrop	069500000	J4	5
	RX1	Motherboard	058021100	P12	9	Xmitter bd w/Multidrop	069500000	J4	9
	TX1/485+	Motherboard	058021100	P12	7	Xmitter bd w/Multidrop	069500000	J4	7
	RS-GND1	Motherboard	058021100	P12	5	Xmitter bd w/Multidrop	069500000	J4	5
06737	**CBL, I2C to AUX I/O (ANALOG IN OPTION**								
	ATX-	Motherboard	058021100	J106	1	Aux I/O PCA	067300000	J2	1
	ATX+	Motherboard	058021100	J106	2	Aux I/O PCA	067300000	J2	2
	LED0	Motherboard	058021100	J106	3	Aux I/O PCA	067300000	J2	3
	ARX+	Motherboard	058021100	J106	4	Aux I/O PCA	067300000	J2	4
	ARX-	Motherboard	058021100	J106	5	Aux I/O PCA	067300000	J2	5
	LED0+	Motherboard	058021100	J106	6	Aux I/O PCA	067300000	J2	6
	LED1+	Motherboard	058021100	J106	8	Aux I/O PCA	067300000	J2	8
06738	**CBL, CPU COM to AUX I/O (USB OPTION**								
	RXD	CPU PCA	067240000	COM1	1	Aux I/O PCA	0673000 or -02	J3	1
	DCD	CPU PCA	067240000	COM1	2	Aux I/O PCA	0673000 or -02	J3	2
	DTR	CPU PCA	067240000	COM1	3	Aux I/O PCA	0673000 or -02	J3	3
	TXD	CPU PCA	067240000	COM1	4	Aux I/O PCA	0673000 or -02	J3	4
	DSR	CPU PCA	067240000	COM1	5	Aux I/O PCA	0673000 or -02	J3	5
	GND	CPU PCA	067240000	COM1	6	Aux I/O PCA	0673000 or -02	J3	6
	CTS	CPU PCA	067240000	COM1	7	Aux I/O PCA	0673000 or -02	J3	7
	RTS	CPU PCA	067240000	COM1	8	Aux I/O PCA	0673000 or -02	J3	8
	RI	CPU PCA	067240000	COM1	10	Aux I/O PCA	0673000 or -02	J3	10
06738	**CBL, CPU COM to AUX I/O (MULTIDROP OPTION**								
	RXD	CPU PCA	067240000	COM1	1	Xmitter bd w/Multidrop	069500000	J3	1
	DCD	CPU PCA	067240000	COM1	2	Xmitter bd w/Multidrop	069500000	J3	2
	DTR	CPU PCA	067240000	COM1	3	Xmitter bd w/Multidrop	069500000	J3	3
	TXD	CPU PCA	067240000	COM1	4	Xmitter bd w/Multidrop	069500000	J3	4
	DSR	CPU PCA	067240000	COM1	5	Xmitter bd w/Multidrop	069500000	J3	5
	GND	CPU PCA	067240000	COM1	6	Xmitter bd w/Multidrop	069500000	J3	6
	CTS	CPU PCA	067240000	COM1	7	Xmitter bd w/Multidrop	069500000	J3	7
	RTS	CPU PCA	067240000	COM1	8	Xmitter bd w/Multidrop	069500000	J3	8
	RI	CPU PCA	067240000	COM1	10	Xmitter bd w/Multidrop	069500000	J3	10
06739	**CBL, CPU ETHERNET TO AUX I/O**								
	ATX-	CPU PCA	067240000	LAN	1	Aux I/O PCA	06730XXXX	J2	1
	ATX+	CPU PCA	067240000	LAN	2	Aux I/O PCA	06730XXXX	J2	2
	LED0	CPU PCA	067240000	LAN	3	Aux I/O PCA	06730XXXX	J2	3
	ARX+	CPU PCA	067240000	LAN	4	Aux I/O PCA	06730XXXX	J2	4
	ARX-	CPU PCA	067240000	LAN	5	Aux I/O PCA	06730XXXX	J2	5
	LED0+	CPU PCA	067240000	LAN	6	Aux I/O PCA	06730XXXX	J2	6
	LED1	CPU PCA	067240000	LAN	7	Aux I/O PCA	06730XXXX	J2	7
	LED1+	CPU PCA	067240000	LAN	8	Aux I/O PCA	06730XXXX	J2	8
06741	**CBL, CPU USB TO FRONT PANEL**								
	GND	CPU PCA	067240000	USB	8	LCD Interface PCA	066970000	J9	
	LUSBD3+	CPU PCA	067240000	USB	6	LCD Interface PCA	066970000	J9	
	LUSBD3-	CPU PCA	067240000	USB	4	LCD Interface PCA	066970000	J9	
	VCC	CPU PCA	067240000	USB	2	LCD Interface PCA	066970000	J9	

Interconnect List, T100
(Reference 0690801A)

Cable PN	Signal	FROM Assembly	PN	J/P	Pin	TO Assembly	PN	J/P	Pin
06746	**CBL, MB TO 06154 CPU**								
	GND	Motherboard	058021100	P12	2	Shield			
	RX0	Motherboard	058021100	P12	14	CPU PCA	067240000	COM1	1
	RTS0	Motherboard	058021100	P12	13	CPU PCA	067240000	COM1	8
	TX0	Motherboard	058021100	P12	12	CPU PCA	067240000	COM1	4
	CTS0	Motherboard	058021100	P12	11	CPU PCA	067240000	COM1	7
	RS-GND0	Motherboard	058021100	P12	10	CPU PCA	067240000	COM1	6
	RTS1	Motherboard	058021100	P12	8	CPU PCA	067240000	COM2	8
	CTS1/485-	Motherboard	058021100	P12	6	CPU PCA	067240000	COM2	7
	RX1	Motherboard	058021100	P12	9	CPU PCA	067240000	COM2	1
	TX1/485+	Motherboard	058021100	P12	7	CPU PCA	067240000	COM2	4
	RS-GND1	Motherboard	058021100	P12	5	CPU PCA	067240000	COM2	6
	RX1	Motherboard	058021100	P12	9	CPU PCA	067240000	485	1
	TX1/485+	Motherboard	058021100	P12	7	CPU PCA	067240000	485	2
	RS-GND1	Motherboard	058021100	P12	5	CPU PCA	067240000	485	3
06910	**CBL, COOLER FAN**								
	+12V RET	Relay PCA	045230100	P12	7	Cooler Fan	013140000		2
	+12V	Relay PCA	045230100	P12	8	Cooler Fan	013140000		1
WR256	**CBL, XMITTER TO INTERFACE**								
		LCD Interface PCA	066970000	J15		Transmitter PCA	068810000	J1	

REVISIONS

REV	DESCRIPTION	DATE	DCN	APPROVED
A	INITIAL RELEASE	9/3/10	5833	KV

Analog Out J1020
Status Out J1017
Control In J1004
RS-232 J1013
RS-485 J1010 & 1011

06739

CN5 CN4 CN3

CPU 06724
Motherboard 058021100

DOM CP34

AUX I/O 06730

06738 USB OPT

J3
W/MD 06950
Xmitter 06881

04671 MD OPT

J27

J12

06738 MD OPT

06746

J106 J108 J109 J110   J15 J107

ANALOG IN OPT 06760

06737

WR256

04488

Cooler Fan 01314

06910

03829

04023

040260200

04562

04105

Flow Mod 0400301 J1

Pre-Amp 0418004 J6 J5 J1

J12 J7 J3 J18

J4

06741

O2 Sensor 04921 J1

J3

TEC 0493101

04437

J5
J9
J10
J11
J17

Relay Board 0452301

J8
J1

J2

UV Ref 0506301 J1

Lamp Drv 06193 J1

Fan 04001

J6

J20

J15
J9
J1

J14

Cntrl Mod 07215

LCD Interface 06697 J2 J10

LCD w/Touchscreen 06790

RX Cell Temp. 04626
IZS Temp 05266
O2 Sensor Temp 04342
Sample/Cal Valve 055560000 P1
Zero Valve 055560000
Hi Span Valve 055560000
Low Span Valve 055560000 P1

AC Power Entrance

036490100

AC Power Switch

04176

PS1 (+5, ±15) SK1 06801 SK2

PS2 (+12) SK1 06802 SK2

0402701 *0448501*

RX Cell Heaters 04625 P1

Shutter 01342

Pump 050510200 05356

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KEY:
1. All part numbers in *Italic* identify cables that are refered to in the accompaning document 069080100.
2. All items in Dashed boxes are optional.

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UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ARE:
FRACTIONS DECIMALS ANGULAR
± 1/32   ±.03[0.76] ±0° 30'
          ±.010[0.25]
DO NOT SCALE DRAWING

TREATMENT
NA

FINISH

SIMILAR TO

THIRD ANGLE PROJECTION

CONTRACT:
NA

APPROVALS	DATE
DRAWN KV	4/10
CHECK	
CCB	
ISSUED	

TELEDYNE
Advanced Pollution Instrumentation
A Teledyne Technologies Company

TITLE
INTERCONNECT DRAWING
T100

SIZE	CAGE CODE NO.	DWG. NO.	REV
B	1JZF4	06908	A

SCALE DNS FILE 06908 SHEET 1 OF 1

SCH, PCA 04003, PRESS/FLOW, 'E' SERIES

S1 — ASCX PRESSURE SENSOR
1 2 3 4 5 6

S2 — ASCX PRESSURE SENSOR
1 2 3 4 5 6

S3 — FLOW SENSOR FM_4
1 2 3
CN_647 X 3

S4 — CON4
1 2 3 4

+15V
R2 1.1K
VR2 LM4040CIZ
C2 1.0UF

+15V
R1 499
VR1 LM4040CIZ
C1 1.0UF

+15V
C3 1.0

TP4 S1/S4_OUT
TP5 S2_OUT
TP3 S3_OUT
TP2 10V_REF
TP1 GND

J1 MINIFIT6
+15V

TELEDYNE
INSTRUMENTS
Advanced Pollution Instrumentation

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APPROVALS   DATE
DRAWN
CHECKED
APPROVED

SIZE B   DRAWING NO. 04354   REVISION D
LAST MOD. 3-Dec-2007   SHEET 1 of 1

D-8

06807C DCN6650

Name
04524-p1.sch

Name
04524-p2.sch

Name
04524-p3.sch

Title
M100E/200E/400E RELAY PCA SCHEMATIC

Size	Number 04522	Revision D
B		

Date: 16-May-2007 Sheet 0 of 0
File: N:\PCBMGR\04522cc\source\04522dd.sch Drawn By:

Schem, M100E/M200E/M400E Relay PCB

General Trace Width Requirements
1. Vcc (+5V) and I2C VCC should be 15 mil
2. Digitial grounds should be at least 20 mils
3. +12V and +12V return should be 30 mils
4. All AC lines (AC Line, AC Neutral, RELAY0 - 4, All signals on JP2) should be 30 mils wide, with 120 mil isolation/creepage distance around them
5. Traces between J7 - J12 should be top and bottom and at least 140 mils.
6. Traces to the test points can be as small as 10 mils.

REV	AUTH	DATE		
B	CAC	10/3/02	CE MARK LINE VOLTAGE TRACE SPACING FIX	
D	RJ	5/16/07	Add alternate thermocouple connectors	

Size	Number	Revision
B	04524	D

Date: 16-May-2007   Sheet 1 of 3
File: N:\PCBMGR\04522cc\source\04522.ddb   Drawn By:

Printed documents are uncontrolled

D-10

06807C DCN6650

Schem, M100E/M200E/M400E Relay PCB

Schematic diagram labels:

THERMOCOUPLE CONNECTOR OMEGA — J15, J15A
THERMOCOUPLE CONNECTOR HAMITHERM

THERMOCOUPLE CONNECTOR OMEGA — J16, J16A
THERMOCOUPLE CONNECTOR HAMITHERM

F3, F4 1/8 AMP FUSE
F5, F6 1/8 AMP FUSE

ZR1 3V, ZR2 3V, ZR3 4.7V, ZR4 4.7V, ZR5 3V, ZR6 3V

R19 3M, R20 3M, R15 10K, R16 10K
R13 10K, R18 10K, R24 6.81K, R23 6.81K
R21 1k, R22 1k, R25 14K, R26 14.3K, R7 20K, R8 20K
R17 5K, R28 5K, R9 10K, R27 10K
R11 1M, R10 1M, R14 1M, R12 1M

C7 0.1, C12 0.01, C10 0.1, C8 0.01, C9 0.1, C14 0.1
C11 0.01, C15 0.01

U7A OPA2277, U7B OPA2277
U8 LT1025, U10 LT1025 — Vin, TOUT, J, K, R-, Gnd

TC1_KCOMPA, TC1_JCOMPA, TC1_GND, TC1_GNDTCA
TC1_JGAINA, TC1_JGAINB, TC1_5MVA, TC1_5MVB
TC2_KCOMPA, TC2_JCOMPA, TC2_GND, TC2_GNDTCA
TC2_JGAINA, TC2_JGAINB, TC2_5MVA, TC2_5MVB
TC2_JCOMPB, TC2_KCOMPB

+15V, -15V

J17 MICROFIT-4 — pins 1 2 3 4

JP5 MICROFIT-20 — TC PROGRAMMING SOCKET
pins 1–20:
1 TC1_JGAINA
2 TC1_5MVA
3 TC1_JCOMPA
4 TC1_KCOMPA
5 TC1_GNDTCA
6 TC2_JGAINA
7 TC2_5MVA
8 TC2_JCOMPA
9 TC2_KCOMPA
10 TC2_GNDTCA
11 TC1_JGAINB
12 TC1_5MVB
13 TC1_JCOMPB
14 TC1_KCOMPB
15 TC1_GNDTCB
16 TC2_JGAINB
17 TC2_5MVB
18 TC2_JCOMPB
19 TC2_KCOMPB
20 TC2_GNDTCB

Notes box:
* GROUNDED THERMOCOUPLES ARE EXPECTED BY DEFAULT
  No extra connections are necessary for grounded thermocouples
* FOR UNGROUNDED THERMOCOUPLES
  short TCX_GNDTCA to TCX_GNDTCB
* FOR K THERMOCOUPLE:
  1) Install CN0000156 for thermocouple connector
  2) Short only TCX_KCOMPA to TCX_KCOMPB on TC Programming Plug
  4) Leave TCX_JCOMPX pins of the plug unconnected
* FOR J THERMOCOUPLE:
  1) Install CN0000155 for thermocouple connector
  2) Short TCX_JCOMPA to TCXJCOMPB on TC Programming Plug
  3) Short TCX_JGAINA to TCX_JGAINB on TC Programming Plug
  4) Leave TCX_KCOMPX pins of the plug unconnected
* DEFAULT OUTPUT IS 10 mV PER DEG C

Printed documents are uncontrolled

Title: Schem, M100E/M200E/M400E Relay PCB
Size: B
Number: 04524
Revision: D
Date: 16-May-2007
Sheet 3 of 3
File: N:\PCBMGR\04522cc\source\04522dd.ddb
Drawn By:

D-12

06807C DCN6650

| | 1 | 2 | 3 | 4 | 5 | 6 |

Interconnections
04181H-1-m100e200e.sch

preamp cktry
04181H-2-m100e200e.SCH

HVPS Cktry
04181H-3-m100e200e.SCH

Title
M100E/200E PMT Preamp PCA

| Size | Number | | Revision |
| B | 04181 | | H |

Date: 10-May-2007 Sheet 0 of 3
File: N:\PCBMGR\04179cc\Source\RevG\04179.ddb Drawn By:

100E/200E PMT PREAMP PCA Schematic

COMP.	100E	200E	0200EU
R18	10K	10K	14K
R15	55K	55K	47K
R10	8.09K	8.09K	10K

ON JP2:

FOR 100E/200E : SHORT PINS 2 &5 ONLY.
FOR 200EU: SHORT PINS 3 & 6 and PINS 2 & 5.

M100E/200E PMT Preamp PCA Schematic

VERSION TABLE:
0100 - M10XE
0200 - M20XE

COMP.	0100	0200
R17	20.0K	10.0 ohms
R44	39.2K	25.5K
R51	10K	not installed
C3	0.1 uF	0.012
C11	11.0	1.0

SEE TABLE
For 1.0 uF use C11.
For 11 uF use C11A & C11B.

NOTES: UNLESS OTHERWISE SPECIFIED

1. CAPACITANCE IS IN MICROFARADS.

2. RESISTORS ARE 1%, 1/4W.

3. RESISTANCE IS IN OHMS.

4. THIS CIRCUIT MUST BE USED
   AS A MATCHED PAIR WITH THE
   TEC CONTROL CIRCUIT

Title		
M100E/200E PMT Preamp PCA Schematic		
Size	Number	Revision
B	04181	H
Date:	10-May-2007	Sheet 2 of 3
File:	N:\PCBMGR\04179cc\Source\RevG\04179H.ddb	Drawn By:

HIGH VOLTAGE SUPPLY

M100E/200E PMT PREAMP PCA Schematic

Size	Number	Revision
B	04181	H

Date: 10-May-2007 Sheet 3 of 3
File: N:\PCBMGR\04179cc\Source\RevG\04179.ddb Drawn By:

Printed documents are uncontrolled

D-16

06807C DCN6650

Note: Once detector is installed and calibrated, the board and detector are a matched set. Do not swap detectors.

FACTORY SELECT

R7 1.0K

R15 1.0K

5K CW
VR1
-15V

C1 0.1uf

R12 4.99M

C9 0.2 uF

R6 1K R5 2K R4 4K R3 8K R2 15.8K R1 34K

R10 100

2 U1
6
OPA124

3

7
C5 N/I

+15V

C3 0.1uf

CR1 12V ZENER

PHOTOCELL D1

R11 1.0K

R14 7.5K

R13 100

TP4 REF

-15V
TP1 -15V

R8 1.0K

C4 1.0uF

4 1 5 U2
2
6
3
OPA124

7
C8 0.1uf

+15V

C7 0.1uf

REF_OUT

C10 N/I

+15V
-15V

PHOTO_ABS

J1
1
2
3
4
5
6
7
8
MICROFIT

+15V
TP2

+15V

C6 1.0uf

TP5

AGND

ABS
TP3

R9 100

C2 N/I

TELEDYNE
INSTRUMENTS
Advanced Pollution Instrumentation

APPROVALS	DATE	**M100E UV REF PCA, DUAL OUT**		
DRAWN		USA		
CHECKED		SIZE A	DRAWING NO. **05064**	REVISION **C**
APPROVED		LAST MOD. 15-M. r-2005	SHEET 1 of 1	

06807C DCN6650

D-17

LAMP POWER CONTROL DAC

TP2
TEST_PLUG
+12V

P1
1
2
3
4
HEADER 4

TP4
TEST_PLUG

VREF
R7
3.9K

TP3
TEST_PLUG
U3
1 Vdd GND 8
2 A0 SDA 7
3 A1 SCL 6
4 Vout PD 5
AD5321-RM8

JP1
JUMPER2

TP1
TEST_PLUG
VDAC

04693_p2
04693_p2.sch
+12V   VDRIVE
LAMP_FDBACK
VREF
ACOMP_2

VDRIVE

RP2D
4.7K

C2
0.1 uF

C3
220

TP5
Drive Volt. ge

LAMP DRIVE POWER STAGE

TP6
Q2 Dr. in V
T1
PE-6196

R20
2.7k, 25W

R4
100

C4
0.01 uF

TP7
Q3 Dr. in V

D3
1N4148

D4
1N4148

D5
1N4148

D6
1N4148

IRF520
Q2

IRF520
Q3

TP8
Prim ry Current

R2
N/I

R3
N/I

C23
N/I

C24
N/I

R21
0.2 Ohms, 2W

TP11
L mp Current

R6
75, 1/4W

R10
75, 1/4W

IPRIMARY

P2
1
2
3
4
5
6
7
8
LAMP OUTPUT

R1
N/I

TP9
L mp Volt. ge
VLAMP

R5
N/I

+12V
Q6
NPN

VCOMP
30K
R22

CC STAGE AMPLIFIER FOR COMP

TP12
ACOMP
ACOMP

R25
10K,1%

R26
50K

R11
47K

LAMP CURRENT FEEDBACK AMPLIFIER

TP10
PreReg_Control

LAMP_FDBACK

R8   10k

C6
0.03 uF

U1B
LM358

RP2A
4.7K
VREF

C5
0.01 uF

D7
7V

RP2B
4.7K

R13
249

PWM CONTROLLER

+12V
R14
10

R12
249

U2
SG3525
3 SYNC   VCC 15   VC 13
11 OUTPUT A   VREF 16
14 OUPUT B   NONINV. INPUT 2
8 SOFT START   CT 5
1 INV. INPUT   DISCHARGE 7
10 SHUTDOWN   RT 6
4 OSC. OUTPUT   GROUND 12
                COMP 9

C9
0.1 uF

VREF

R15
232

R16
3.9K

C11
0.0047 uF

C12
0.1 uF

C7
0.01 uF

R17
47K

R18
40k

DAC I2C ADDRESS

A0	A1	WRITE ADDRESS	READ ADDRESS	ASSY NUMBER
0	0	18	19	TBD
0	1	1A	1B	TBD
1	0	1C	1D	TBD
1	1	1E	1F	TBD

Applies to PCAs: 04540 -01 and -02

BLINK MULTIVIBRATOR

VDAC

R27   40K
R28   5.1K

D8
1N914

+12V

R34   40K

U1A
LM358

R29   R30
100K   47K

C14
1 uF

R31
47K

ACOMP

R32
40K

R35
40K

R36
20K

VSET

R33
40K

PRIMARY WINDING OVERCURRENT CUTOFF

D1
1N914

D2
7v ZENER

U4B

D9
1N914

VCOMP

IPRIMARY

R38
4.7K

VREF

R39
255K

U4B
LM358

C16
0.01 uF

R40
30K

HYSTERIESIS SET RESISTORS FOR PWM ERROR COMPARATOR

REV.	DATE	CHANGE DESCRIPTION	INITIAL
A	5/1/03	CREATED	CAC
B	6/1/03	Ch. nged l. yout on 1st switvher st. ge	CAC
C	9/3/03	Ch. nged R15 v. lue	CAC
C1	11/18/03	Ch. nged R43 & C15 v. lues	CAC

Error : LOGO.BMP file not found.

Sch, Bursting UV Lamp Drv, M100E
Used for PCA 04692

APPROVALS	DATE
DRAWN CAC	5/1/03
CHECKED	
APPROVED	

SIZE B
DRAWING NO. 04693
REVISION E
LAST MOD. 2-Jun-2004
SHEET 1 of 2

Title: Sch, Bursting UV L. mp Drv, M100E

Size	Number		Revision
B	04693		E

| Date: | 2-Jun-2004 | Sheet of 2 | 2 |
| File: | N:\PCBMGR\RELEASED\04691CC\source\04693.ddb | | |

06807C DCN6650

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TEC Amplifier PCB

Size	Number	Revision
B	04932	C

Date: 13-Jan-2005 Sheet 1 of 1
File: N:\PCBMGR\UNREL\04930PW\Protel\049Drawn By: RJ

JP1
1
2
3
4
5
6
7
8

R1
Not Used

R2
22

Title	SCH, E-Series Analog Output Isolator, PCA 04467		
Size	Number		Revision
A	04468		B
Date:	6/28/2004	Sheet of	
File:	N:\PCBMGR\..\04468B.sch	Drawn By:	

Schematic for E Series G5 Motherboard PCA PN 05802

Notes:

1) This schematic is for PCA 05802
2) This schematic is for PCB 05801

Title: Schematic for E Series G5 Motherboard PCA PN 05802

Size	Number	Revision
Orcad B	05803	B

Date: 11-May-2009

Sheet 1 of 8

File: N:\PCBMGR\05801RJ-E-series Motherboard\Documentation 5\Source\05801b.ddb

TX for Com1
DS1
A · K
LED, RED
R11
4.9K, 5%

RX for Com1
DS2
K · A
LED, GRN, smt 1206
R12
4.9K, 5%

J12
1 RX0
2 RTS0
3 TX0
4 CTS0
5 RS-GND0
6 RX1
7 RTS1
8 TX1
9 CTS1
10 RS-GND1
11
12
13
14
INLINE-12

VCC

R1
2.2K, 5%

DS4
1 · 2
LED, RED
TX for Com2

R2
2.2K, 5%

DS3
2 · 1
LED, GRN
RX for Com2

TV1
TV ARRAY
SMDA15LCC

-15V
R111
10k, 1%

DCE side of switch is side towards pin 1.

R13
NOT INSTALLED
VCC

R14
NOT INSTALLED

R10
NOT INSTALLED

TV2
SMDA15LCC
TV ARRAY

SW1001
SW SLIDE-4PDT

J1010
DB9 FEMALE
1 RX1
2 TX1
3
4
5 RS-GND1
6
7 RTS1
8 CTS1
9
Com2 – RS232-B/RS485

J1013
1 NC
2 RXD
3 TXD
4 NC
5 GND
6 NC
7 RTS
8 CTS
9 NC
DB9M
Com1 – RS232-A

DTE

Z1 Z2 Z3
MOUNTING HOLE MOUNTING HOLE MOUNTING HOLE

MT6 MT7 MT8 MT9
MOUNTING HOLE MOUNTING HOLE MOUNTING HOLE MOUNTING HOLE

MT1 MT2 MT3 MT4 MT5
MOUNTING HOLE MOUNTING HOLE MOUNTING HOLE MOUNTING HOLE MOUNTING HOLE

TP13 TP14 TP15 TP16 TP17 TP18 VCC +12V +12VRET +15V -15V

J15
8 +12V
7 +12RET
1 DGND
4 +15V
6 -15V
3 AGND
2 +5V
5 AGND
9 EGND
10 CHASGND
MOLEX-10
AUXCDC CPOWERCIN

D1
MBRS340CT
DD_71
D9
MBRS340CT
R35
NOT INSTALLED

D1, D9 & R35 must be
within 1" of J15

VCC
C1
10 uF, 35V, TANTALUM
C2
10 uF, 35V, TANTALUM

Title
Schematic for E Series G5 Motherboard PCA PN 05802
Size   Number   Revision
Orcad B   05803   B
Date: 11-May-2009   Sheet 2of 8
File: N:\PCBMGR\05801RJ-E-series Motherboard\Orcad\Revision 5\Source\05801b.ddb

This is a schematic diagram.

Schematic for E Series G5 Motherboard PCA PN 05802

Schematic for E Series G5 Motherboard PCA PN 05802

CONTROL INPUTS

Place these termination resistors at the end of each data line. Each data line should be laid out as a daisy-chain, the signal passing from one IC to the next.

Title		
Schematic for E Series G5 Motherboard PCA PN 05802		
Size	Number	Revision
Orcad B	05803	B
Date:	11-May-2009	Sheet 6of 8
File:	N:\PCBMGR\05801RJ-E-series Motherboard\Documentation 5\Source\05801b.ddb	

DIGITAL OUTPUTS

A STATUS OUTPUTS

RESETTABLE FUSE, 0.3A, 60V

DIODE, SCHOTTKY

EXT +5V OUT

FE BEAD

Title
Schematic for E Series G5 Motherboard PCA PN 05802

Size	Number	Revision
Orcad B	05803	B

| Date: | 11-May-2009 | Sheet 7of | 8 |
| File: | N:\PCBMGR\05801RJ-E-series Motherboard\Documentation 5\Source\05801b.ddb | | |

DIGITAL OUTPUTS

VCC

RN7
510x8

U17
74HC574
OE
CLK
D1 Q1
D2 Q2
D3 Q3
D4 Q4
D5 Q5
D6 Q6
D7 Q7
D8 Q8

SHDN
SHDN
DIGIO0
IOW
U59C
74HC32

D0
D1
D2
D3
D4
D5
D6
D7

D[0..7]

U16 PS2702-4

U18 PS2702-4

L32
L31 FE BEAD

L36
L35 FE BEAD

L59 FE BEAD

10000 pF
10000 pF

C67 C68 C70
C69

C95 C71 C72 C73 C74
10000 pF
10000 pF 10000 pF

J1008
1
2
3
4
5
6
7
8
9
10
11
12
13
14
TERMBLOCK-14

CONTROL OUTPUTS

CO EXT RET

EXTERNAL CONNECTION
ENCLOSE SIGNS

VCC

RN5
510x8

U19 PS2702-4

U21
74HC574
OE
CLK
D1 Q1
D2 Q2
D3 Q3
D4 Q4
D5 Q5
D6 Q6
D7 Q7
D8 Q8

SHDN
DIGIO4
IOW
U20A
74HC32

D0
D1
D2
D3
D4
D5
D6
D7

L40
L39 FE BEAD

10000 pF
C75 C76 C77 C78
10000 pF

+12V
D2
DIODE, SCHOTTKY

K1 RELAY SPDT

R58
2.2K, 5%
Q1
SO2222

+12V
D3
DIODE, SCHOTTKY

K2 RELAY SPDT

R6
2.2K, 5%
Q2
SO2222

+12V
D4
DIODE, SCHOTTKY

K3 RELAY SPDT

R7 2.2K, 5%
Q3
SO2222

+12V
D5
DIODE, SCHOTTKY

K4 RELAY SPDT

R8
2.2K, 5%
Q4
SO2222

+12VRET

J1009
1
2
3
4
5
6
7
8
9
10
11
12
TERMBLOCK-12

EXTERNAL
REAR PANEL
ALARM OUTPUTS

Title
Schematic for E Series G5 Motherboard PCA PN 05802

Size
Orcad B

Number
05803

Revision
B

Date: 11-May-2009
File: N:\PCBMGR\05801RJ-E-series Motherboard\Orientation 5\Source\05801b.ddb

Sheet 8of 8

Make	Model	JP2	JP3
FEMA	GM800480W	1-2, 4-5, 7-8, 10-11, 13-14, 16-17	1-2, 4-5, 7-8, 10-11
Data Image	FG0700A0DSWBG01	3-2, 6-5, 9-8, 12-11, 15-14, 18-17	2-3, 5-6, 8-9, 11-12
United Radiant Tech.	UMSH-8173MD-1T	2-3, 4/5/6 NC, 7/8/9 NC, 10-11, 13-14, 16/17/18 NC	2-3, 5-6, 8-9, 11-12

Title: GUI Interface

Size: B
Number: 06698
Revision: D

Date: 6/24/2010
File: N:\PCBMGR\...\06696.P1.R3.schdoc
Sheet 1 of 4
Drawn By: RT

Backlight Brightness Control

Control Mode	R22	R27	R31
Remote – Video Port	NO	A	NO
Remote – I2C	YES	B	NO
Fixed Bright (default)	NO	B	B

Title: GUI Interface

Size: B
Number: 06698
Revision: D

Date: 6/24/2010
Sheet 2 of 4
File: N:\PCBMGR\..\06696.P2.R3.schdoc
Drawn By: RT

06807C DCN6650

GUI Interface

Configuration Select

Mode	R32	R45
Default	A	A
MBUS	B	B

Install 100K for A, 0 Ohm for B

Title	GUI Interface	
Size	Number	Revision
B	06698	D
Date:	6/24/2010	Sheet 3 of 4
File:	N:\PCBMGR\..\06696.P3.R3.schdoc	Drawn By: RT

TOUCH SCREEN INTERFACE CIRCUITRY (TBD)

From ICOP CPU

MT1 MT2

CHASSIS-0 CHASSIS

To LCD Display

+3.3V

J2 Header 22X2

VAD0	1 2	VAD1
VAD2	3 4	VAD3
	5 6	
VAD6	7 8	VAD7
VAD8	9 10	VAD9
VAD10	11 12	VAD11
	13 14	
	15 16	
	17 18	
	19 20	
	21 22	
VBD2	23 24	VBD3
VBD4	25 26	VBD5
VBD6	27 28	VBD7
VBD10	29 30	VBD11
	31 32	
	33 34	VBGCLK
	35 36	VBDE
	37 38	
	39 40	
	41 42	
	43 44	

22.1
R2

R1
10K

U1

VAD6	44 D0	41 Y0_N
VAD7	45 D1	40 Y0_P
VAD8	47 D2	39 Y1_N
VAD9	48 D3	38 Y1_P
VAD10	1 D4	35 Y2_N
VAD11	3 D5	34 Y2_P
VBD10	4 D6	
VBD11	6 D7	26 CLKIN
VAD0	7 D8	33 CLKOUT_N
VAD1	9 D9	32 CLKOUT_P
VAD2	10 D10	
VAD3	12 D11	27
VBD2	13 D12	14
VBD3	15 D13	43
VBD4	16 D14	
VBD5	18 D15	2
VBD6	19 D16	8
VBD7	20 D17	21
	22 D18	
BACKL	23 D19	37
VBDE	25 D20	29

Y0M
Y0P
Y1M
Y1P
Y2M
Y2P

CLKIN
CLKOUTM
CLKOUTP

SHTDN
NC
NC

VCC
VCC
VCC

LVDSVCC
PLLVCC

+3.3V

5 GND 42 VLDSGND
11 GND 36 VLDSGND
17 GND 31 VLDSGND
24 GND 30 PLLGND
46 GND 28 PLLGND

SN75LVDS84A

J1

Y2_P	1	MH1
	2	MH2
Y2_N	3	MH3
Y1_P	4	MH4
	5	
Y1_N	6	
Y0_P	7	
	8	
Y0_N	9	CHASSIS
CLKOUT_P	10	
	11	
CLKOUT_N	12	
	13	
	14	
	15	
	16	
	17	
	18	+3.3V
	19	

G3168-05000101-00

BACKL

+3.3V

J3

	1 2	
Y0_P	3 4	Y0_N
Y1_P	5 6	Y1_N
Y2_N	7 8	Y2_P
CLKOUT_N	9 10	CLKOUT_P
	11 12	
	13 14	

Header 7X2

+3.3V

C1 22uF/6.3V JMK316BJ226KL
C2 C3 0.1 0.01
C4 C5 0.1 0.01
C6 C7 0.1 0.01
C8 C9 0.1 0.01
C10 C11 0.1 0.01

Title	LVDS, Transmitter Board	
Size A	Number 06882	Revision B
Date: 5/7/2010		Sheet 1 of 1
File: N:\PCBMGR\..\06882-P1-R0.SchDoc		Drawn By: RT

U6

1   6
2   5
3   4

SP3050

.01/2KV
C18

R19
75
R20
75

CHASSIS

R13
0

J1
12   11
1
2
16   3
15   4
14   5
13   6
7
8
10   9

CONN_RJ45_LED

CHASSIS

ATX+
ATX-
ARX+
LED0-
LED0+
ARX-
LED1+
LED1-

STRAIGHT THROUGH ETHERNET

J2
2
1
4
3
6
5
8
7

DF11-8DP-2DS(24)

TP1

SDA

P2
1
2
3
4
5
6
7
8

Header 8

SDA

SCL

SCL

P3
1
2
3
4
5
6
7
8

Header 8

R10
2.2k

DS3
GRN

GND

+5V

C17
100uF

TP3

GND

U8
4
12
11
1

VDD1   VDD2
LME0505
GND1   GND2

5
14
13
7

+5V-OUT

ISO-GND

L1
47uH

+5V-ISO

C28
4.7uF

R16
1k

TP2

DCN:6092

PRINTED DOCUMENTS ARE UNCONTROLLED

Title   Auxiliary I/O Board (PWR-ETHERNET)

Size   A

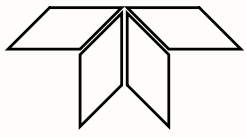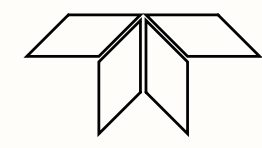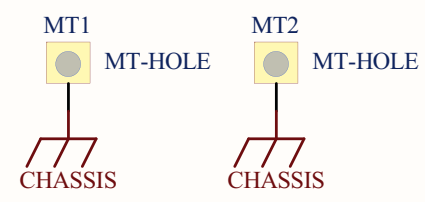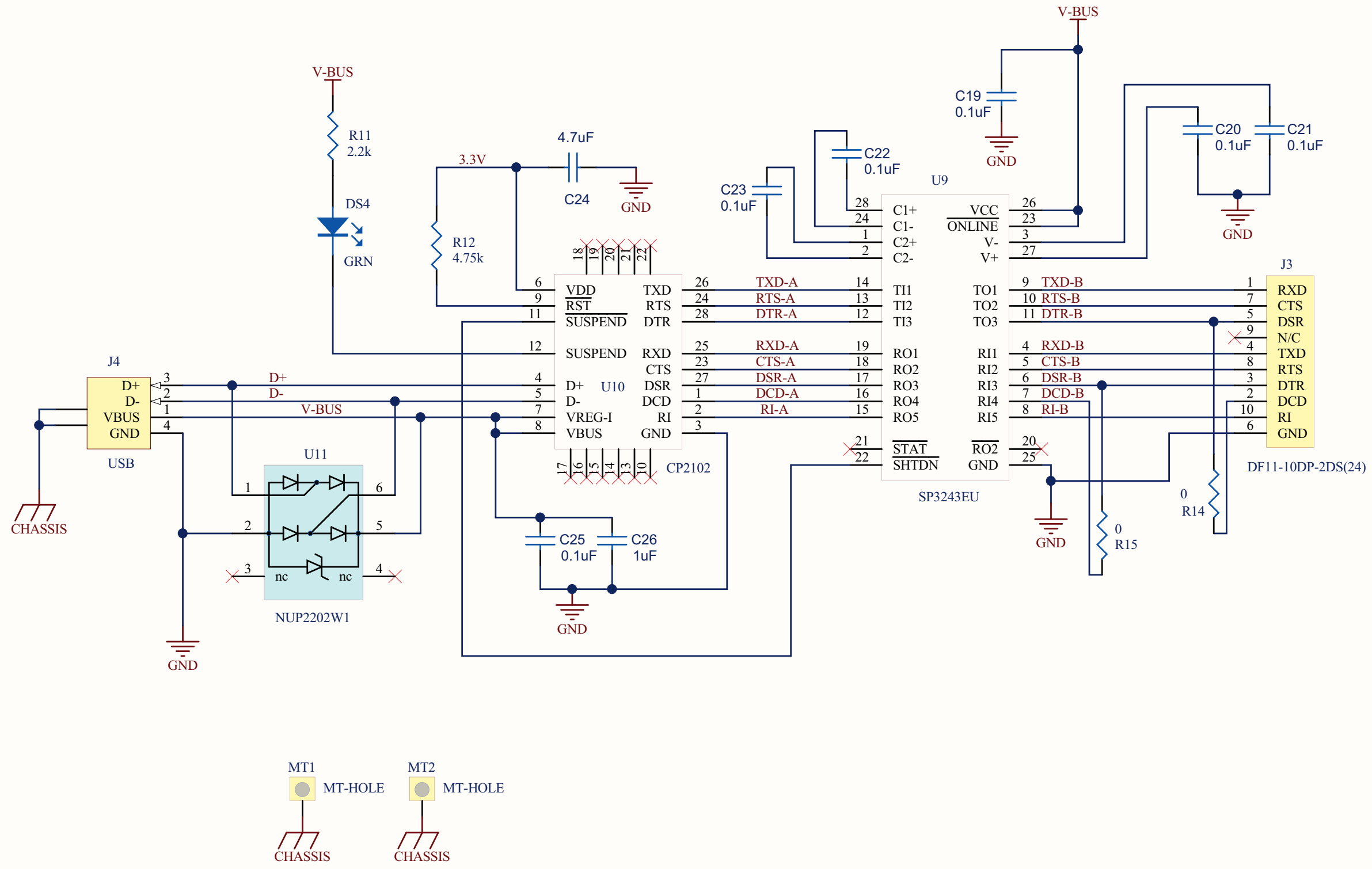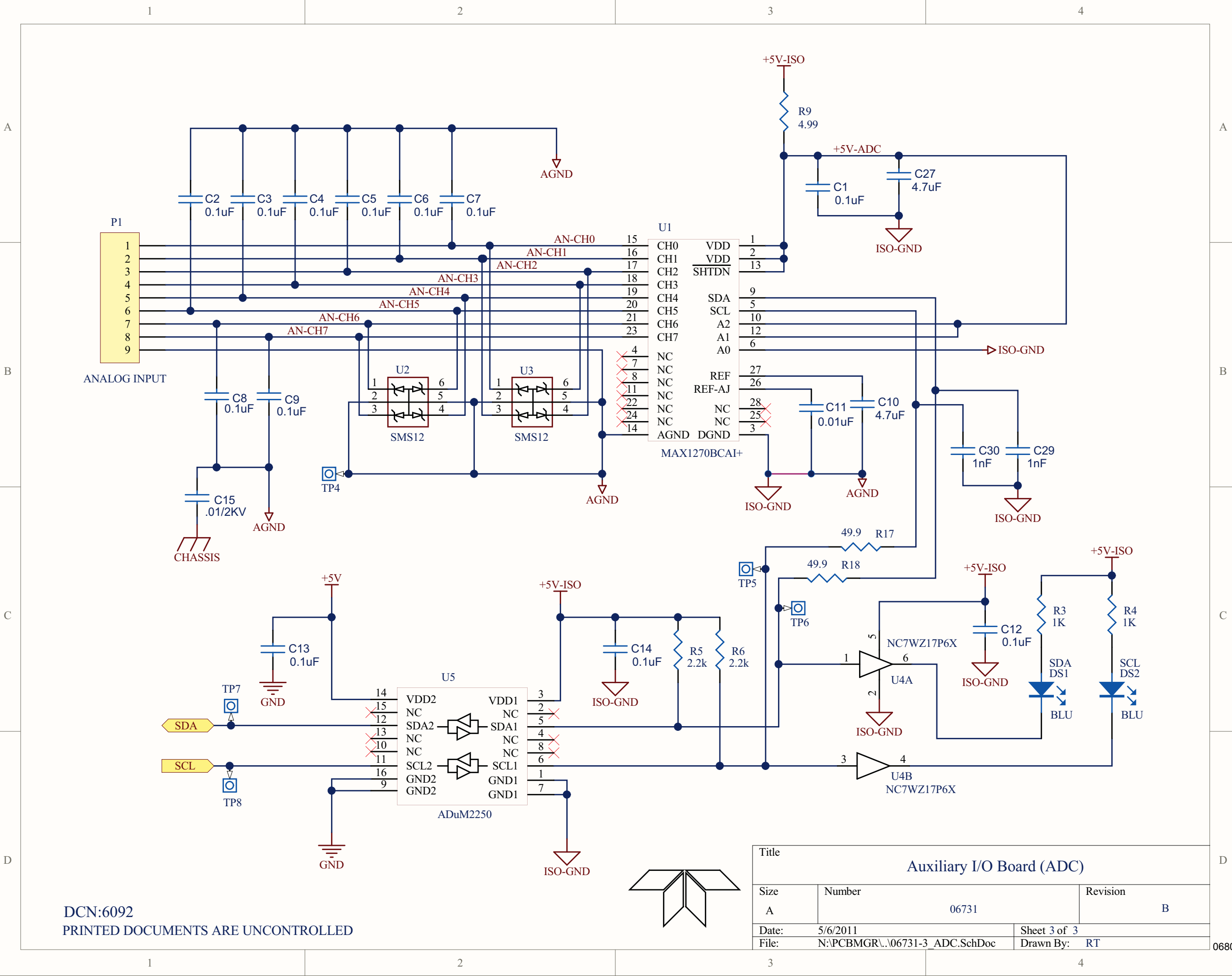Number   06731

Revision   B

Date: 5/6/2011   Sheet 1 of 3

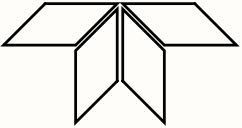File: N:\PCBMGR\..\06731-1_ETHERNET.SchDoc   Drawn By: RT

V-BUS

R11
2.2k

DS4
GRN

R12
4.75k

3.3V

4.7uF
C24
GND

V-BUS

C19
0.1uF
GND

C22
0.1uF

C23
0.1uF

C20
0.1uF

C21
0.1uF

GND

U9

28	C1+	VCC	26
24	C1-	ONLINE	23
1	C2+	V-	3
2	C2-	V+	27

U10 — CP2102

6	VDD	TXD	26	TXD-A
9	RST	RTS	24	RTS-A
11	SUSPEND	DTR	28	DTR-A
12	SUSPEND	RXD	25	RXD-A
		CTS	23	CTS-A
4	D+	DSR	27	DSR-A
5	D-	DCD	1	DCD-A
7	VREG-I	RI	2	RI-A
8	VBUS	GND	3	

SP3243EU

14	TI1	TO1	9	TXD-B
13	TI2	TO2	10	RTS-B
12	TI3	TO3	11	DTR-B
19	RO1	RI1	4	RXD-B
18	RO2	RI2	5	CTS-B
17	RO3	RI3	6	DSR-B
16	RO4	RI4	7	DCD-B
15	RO5	RI5	8	RI-B
21	STAT	RO2	20	
22	SHTDN	GND	25	

J3 — DF11-10DP-2DS(24)

1	RXD
7	CTS
5	DSR
9	N/C
4	TXD
8	RTS
3	DTR
2	DCD
10	RI
6	GND

GND

0
R15

0
R14

J4 — USB

3	D+
2	D-
1	VBUS
4	GND

D+
D-
V-BUS

CHASSIS

U11 — NUP2202W1

1		6
2		5
3	nc	nc	4

GND

C25
0.1uF

C26
1uF

GND

MT1 MT-HOLE
CHASSIS

MT2 MT-HOLE
CHASSIS

DCN:6092
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Title	Auxiliary I/O Board (USB)	
Size	Number	Revision
A	06731	B
Date:	5/6/2011	Sheet 2 of 3
File:	N:\PCBMGR\..\06731-2_USB.SchDoc	Drawn By: RT

Auxiliary I/O Board (ADC)

Size	Number	Revision
A	06731	B

Date: 5/6/2011 | Sheet 3 of 3
File: N:\PCBMGR\..\06731-3_ADC.SchDoc | Drawn By: RT

DCN:6092

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D-38

06807C DCN6650